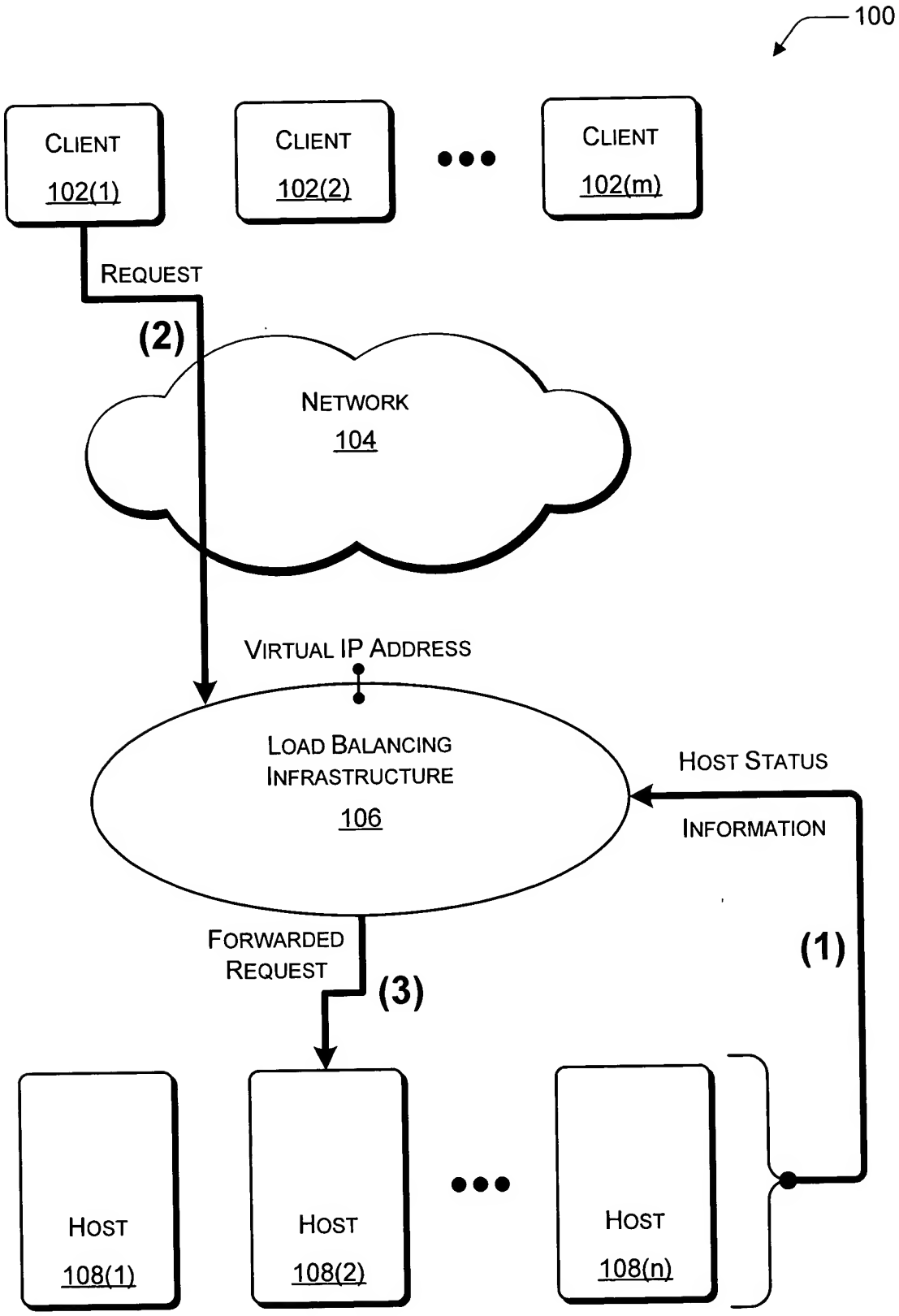

100
CLIENT
102(1)
CLIENT
102(2)
CLIENT
102(m)
REQUEST
(2)
NETWORK
104
VIRTUAL IP ADDRESS
LOAD BALANCING
INFRASTRUCTURE
106
HOST STATUS
INFORMATION
(1)
FORWARDED
REQUEST
(3)
HOST
108(1)
HOST
108(2)
HOST
108(n)

FIG. 1

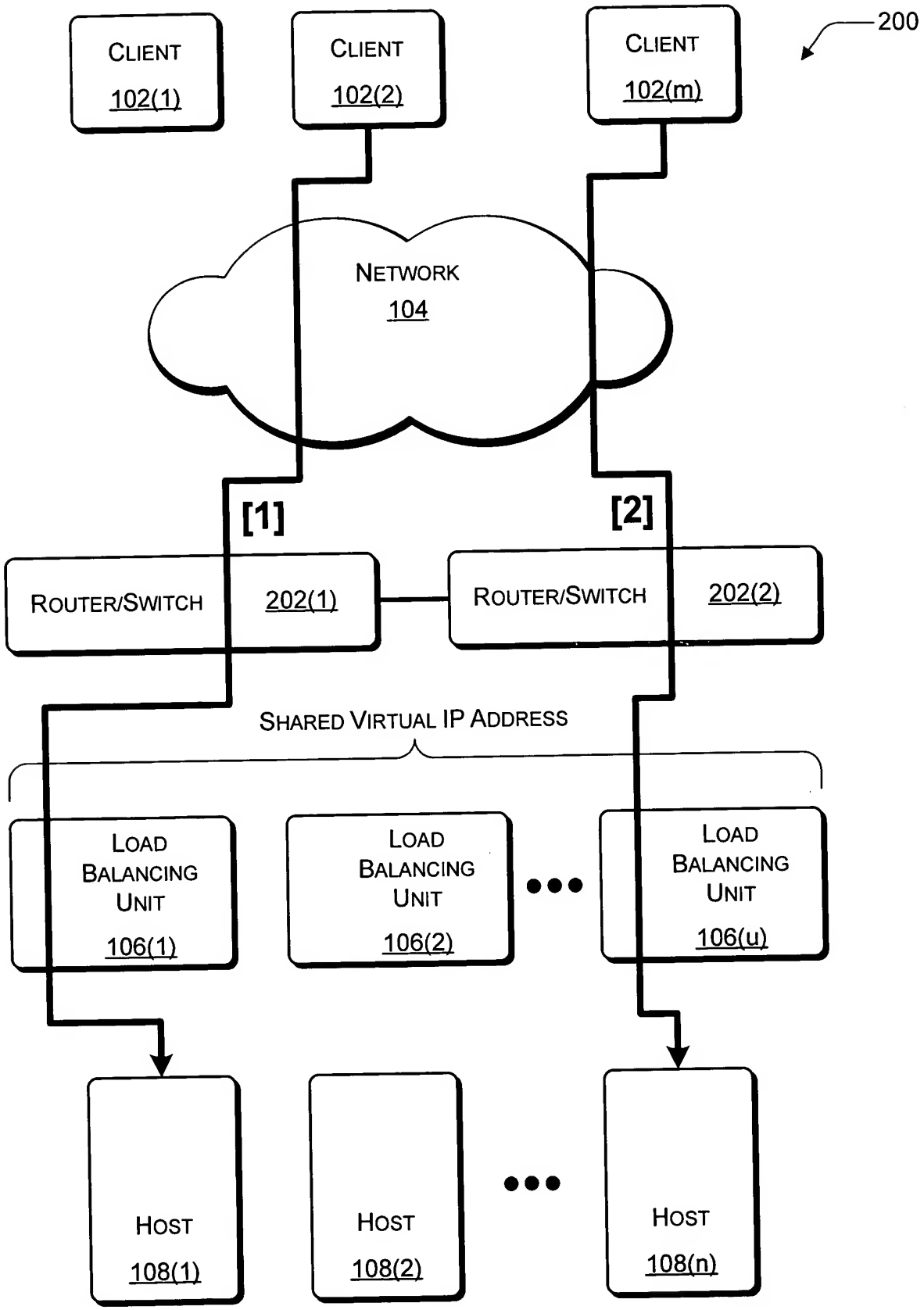

200
CLIENT
102(1)
CLIENT
102(2)
CLIENT
102(m)
NETWORK
104
[1]
[2]
ROUTER/SWITCH
202(1)
ROUTER/SWITCH
202(2)
SHARED VIRTUAL IP ADDRESS
LOAD BALANCING UNIT
106(1)
LOAD BALANCING UNIT
106(2)
LOAD BALANCING UNIT
106(u)
HOST
108(1)
HOST
108(2)
HOST
108(n)

FIG. 2

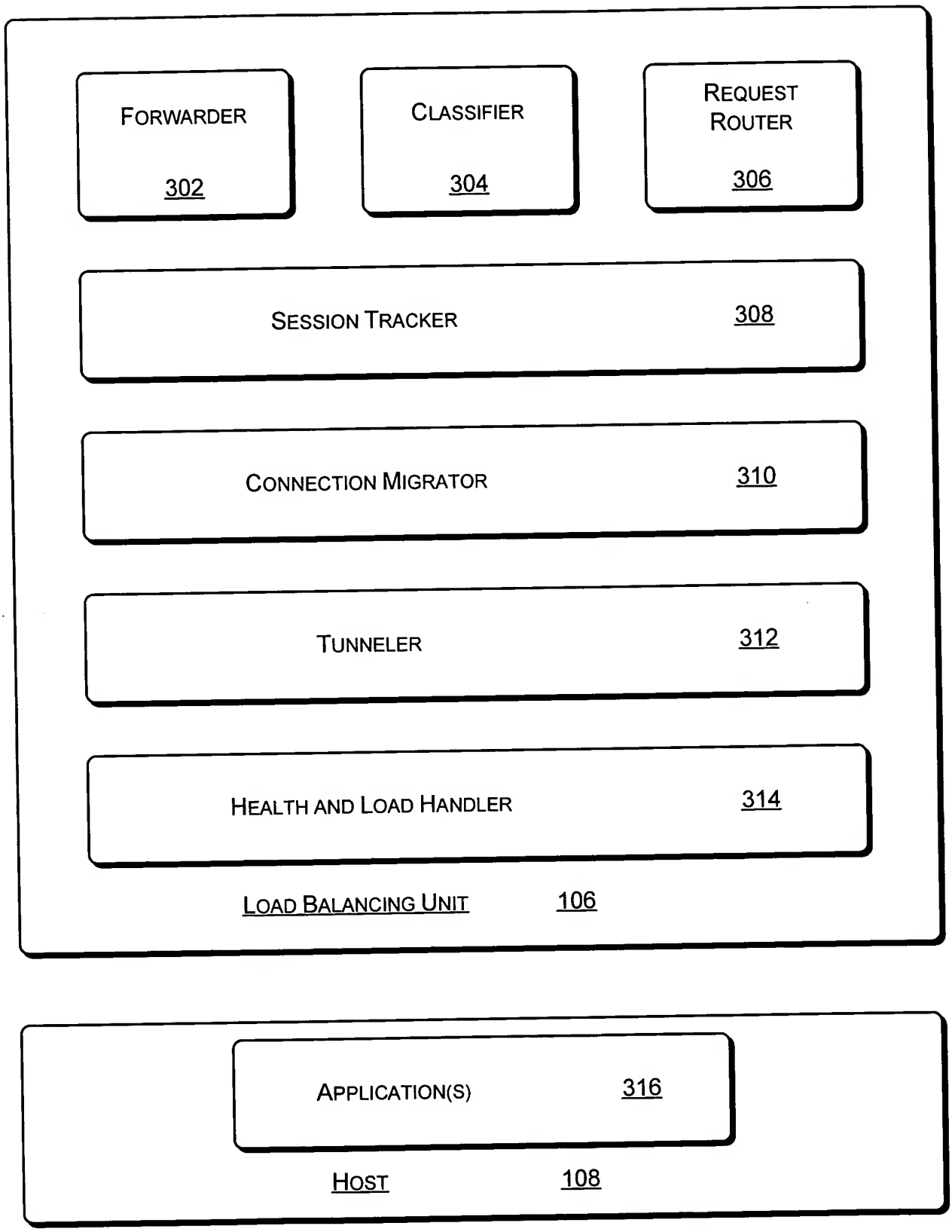

FORWARDER
302
CLASSIFIER
304
REQUEST ROUTER
306
SESSION TRACKER
308
CONNECTION MIGRATOR
310
TUNNELER
312
HEALTH AND LOAD HANDLER
314
LOAD BALANCING UNIT
106
APPLICATION(S)
316
HOST
108

FIG. 3

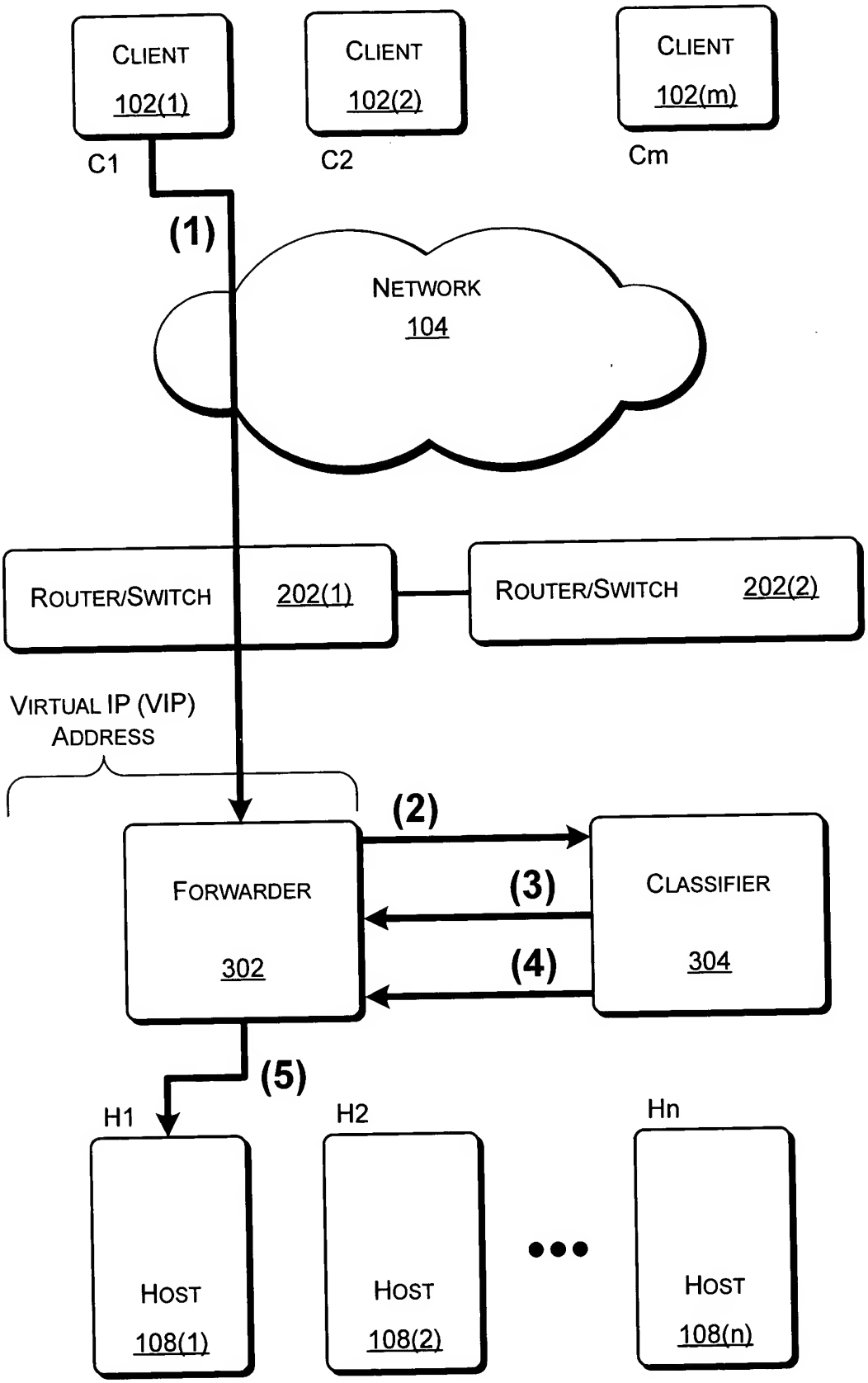

CLIENT
102(1)
CLIENT
102(2)
CLIENT
102(m)
C1
C2
Cm
(1)
NETWORK
104
ROUTER/SWITCH
202(1)
ROUTER/SWITCH
202(2)
VIRTUAL IP (VIP)
ADDRESS
(2)
FORWARDER
302
(3)
(4)
CLASSIFIER
304
(5)
H1
H2
Hn
HOST
108(1)
HOST
108(2)
HOST
108(n)

FIG. 4

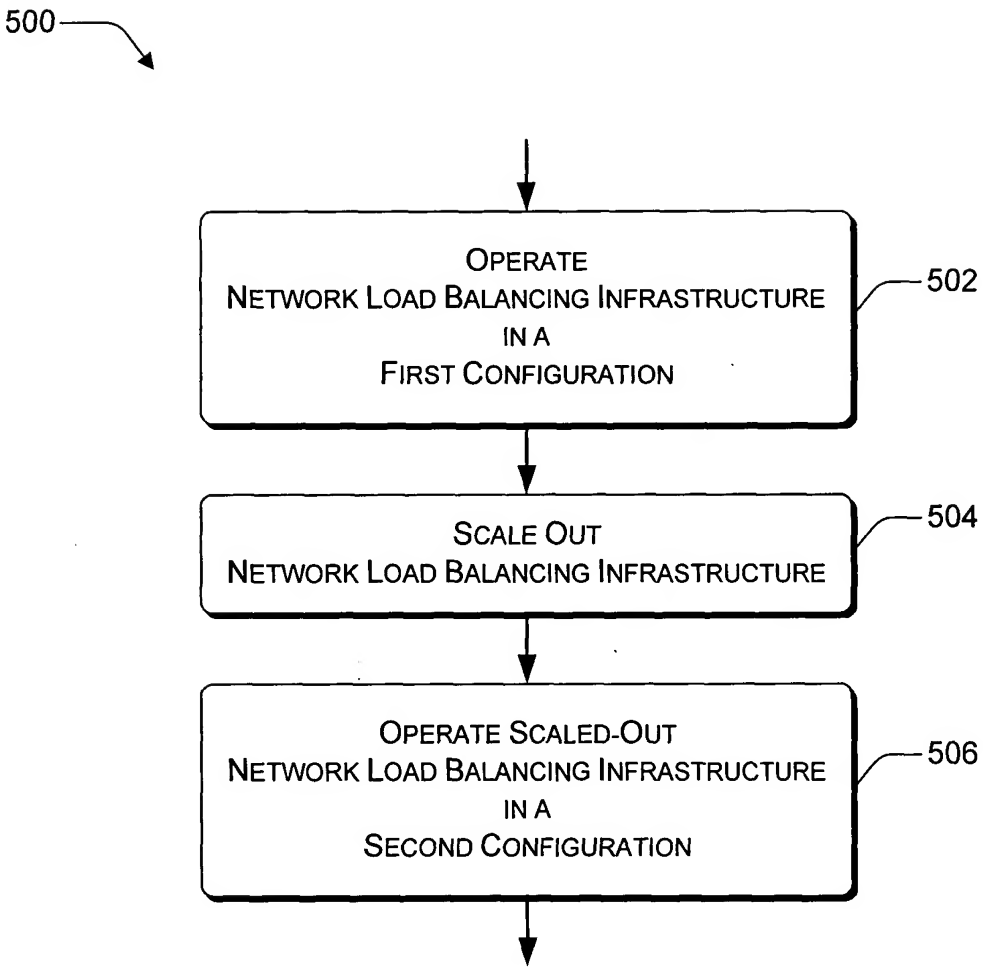
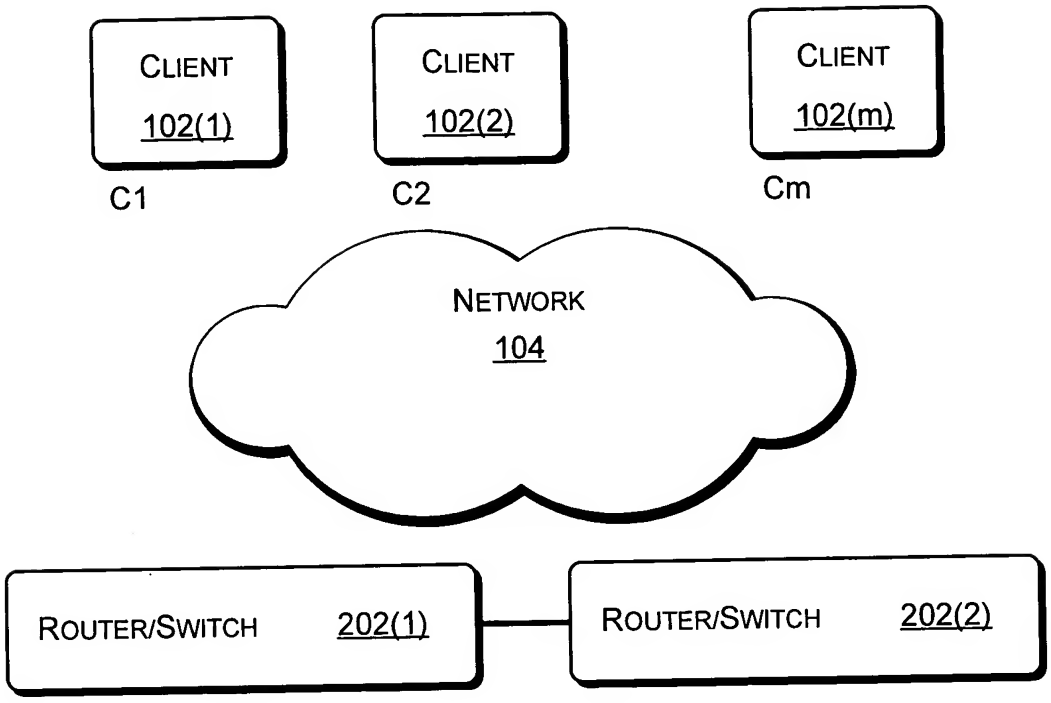

500
OPERATE NETWORK LOAD BALANCING INFRASTRUCTURE IN A FIRST CONFIGURATION
502
SCALE OUT NETWORK LOAD BALANCING INFRASTRUCTURE
504
OPERATE SCALED-OUT NETWORK LOAD BALANCING INFRASTRUCTURE IN A SECOND CONFIGURATION
506

FIG. 5


CLIENT
102(1)
C1
CLIENT
102(2)
C2
CLIENT
102(m)
Cm
NETWORK
104
ROUTER/SWITCH 202(1)
ROUTER/SWITCH 202(2)

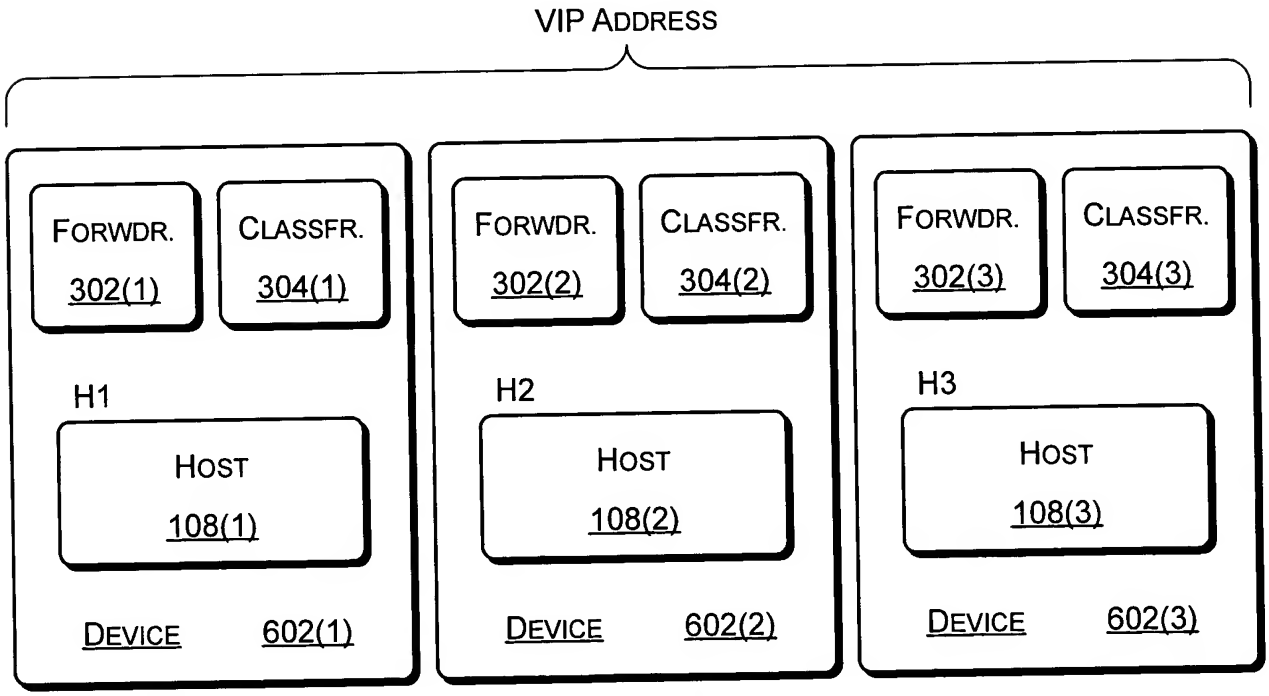

VIP ADDRESS
FORWDR.
302(1)
CLASSFR.
304(1)
H1
HOST
108(1)
DEVICE 602(1)
FORWDR.
302(2)
CLASSFR.
304(2)
H2
HOST
108(2)
DEVICE 602(2)
FORWDR.
302(3)
CLASSFR.
304(3)
H3
HOST
108(3)
DEVICE 602(3)

FIG. 6

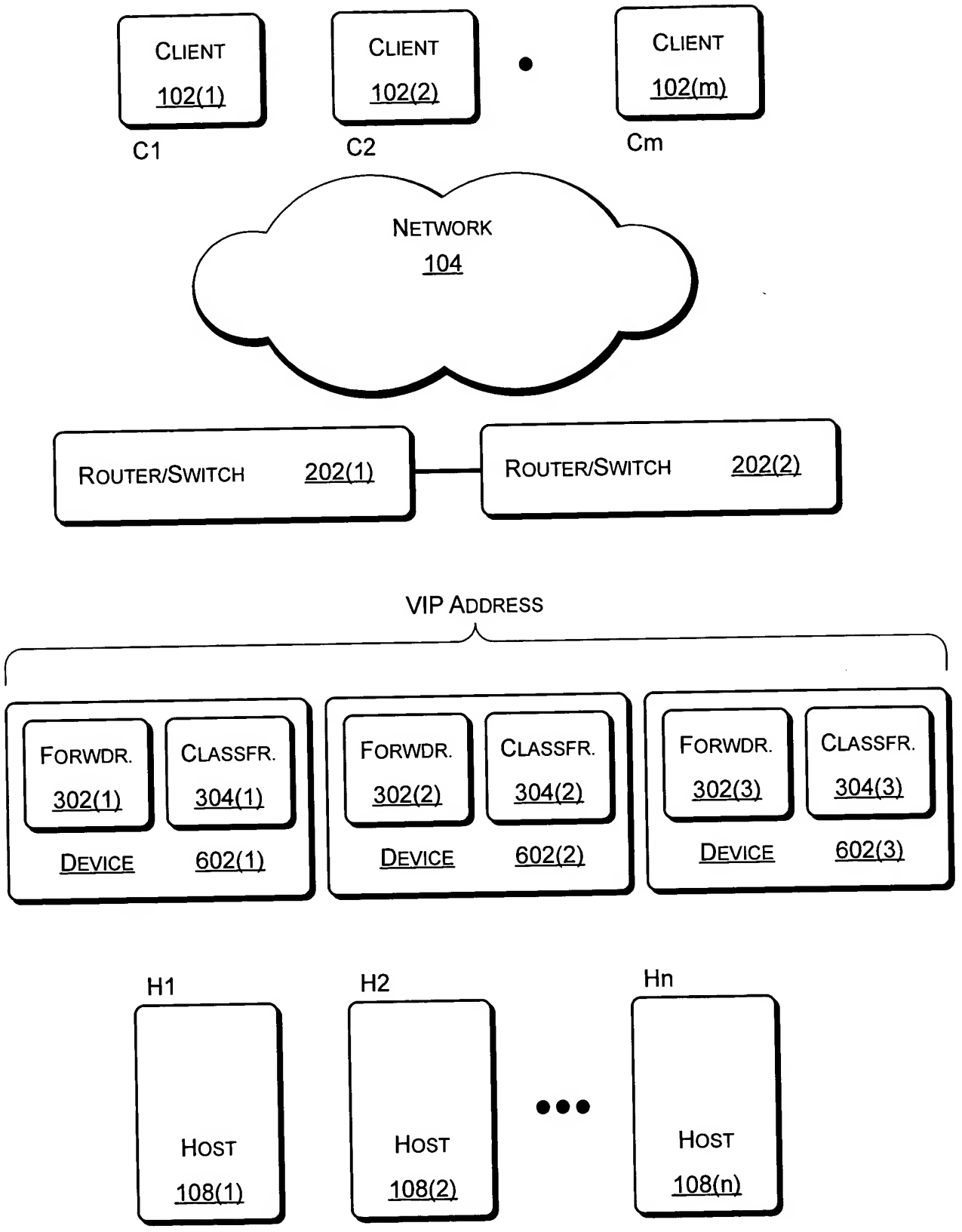

CLIENT
102(1)
C1
CLIENT
102(2)
C2
CLIENT
102(m)
Cm
NETWORK
104
ROUTER/SWITCH 202(1)
ROUTER/SWITCH 202(2)
VIP ADDRESS
FORWDR.
302(1)
CLASSFR.
304(1)
DEVICE 602(1)
FORWDR.
302(2)
CLASSFR.
304(2)
DEVICE 602(2)
FORWDR.
302(3)
CLASSFR.
304(3)
DEVICE 602(3)
H1
HOST
108(1)
H2
HOST
108(2)
Hn
HOST
108(n)

FIG. 7

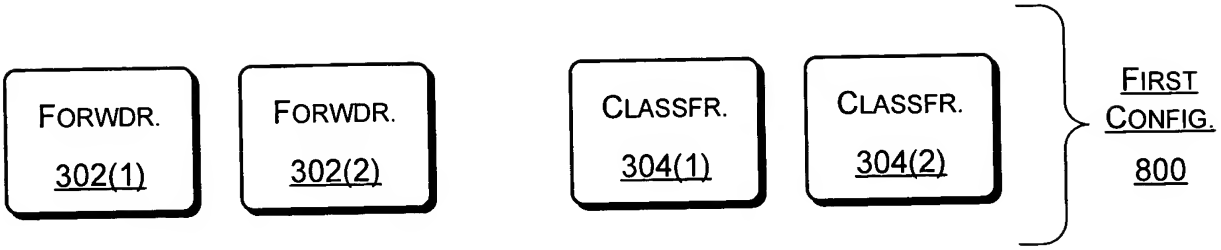

FORWDR. 302(1)
FORWDR. 302(2)
CLASSFR. 304(1)
CLASSFR. 304(2)
FIRST CONFIG. 800

FIG. 8A

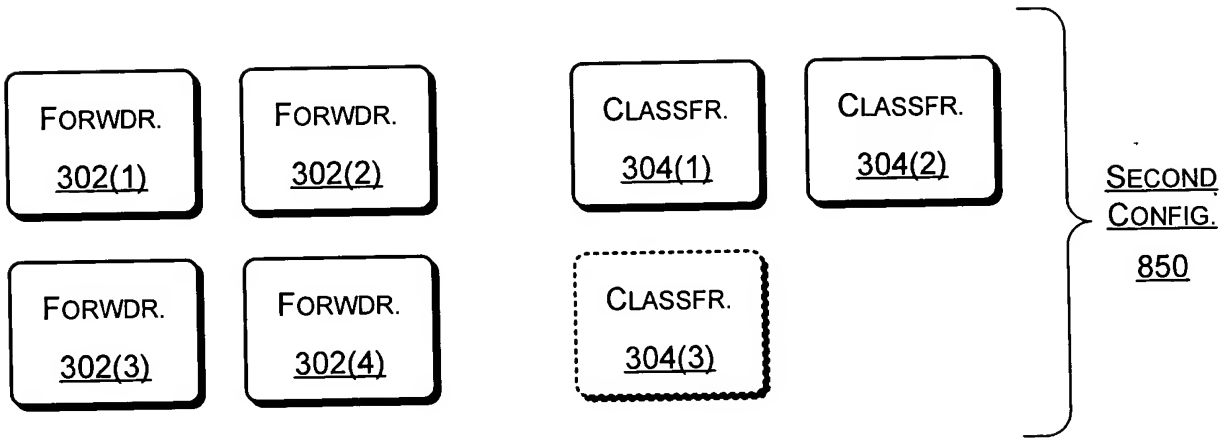

FORWDR. 302(1)
FORWDR. 302(2)
FORWDR. 302(3)
FORWDR. 302(4)
CLASSFR. 304(1)
CLASSFR. 304(2)
CLASSFR. 304(3)
SECOND CONFIG. 850

FIG. 8B

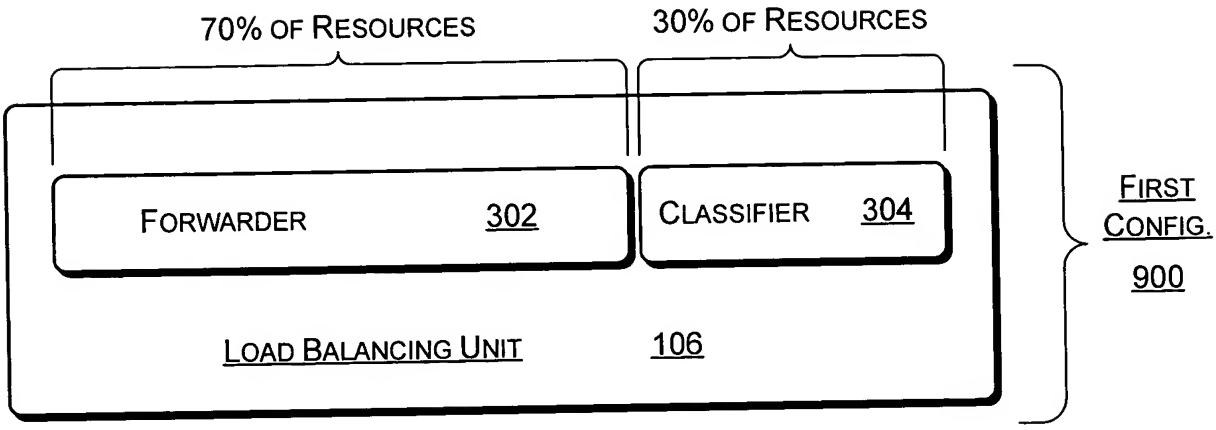

70% OF RESOURCES
30% OF RESOURCES
FORWARDER 302
CLASSIFIER 304
LOAD BALANCING UNIT 106
FIRST CONFIG. 900

FIG. 9A

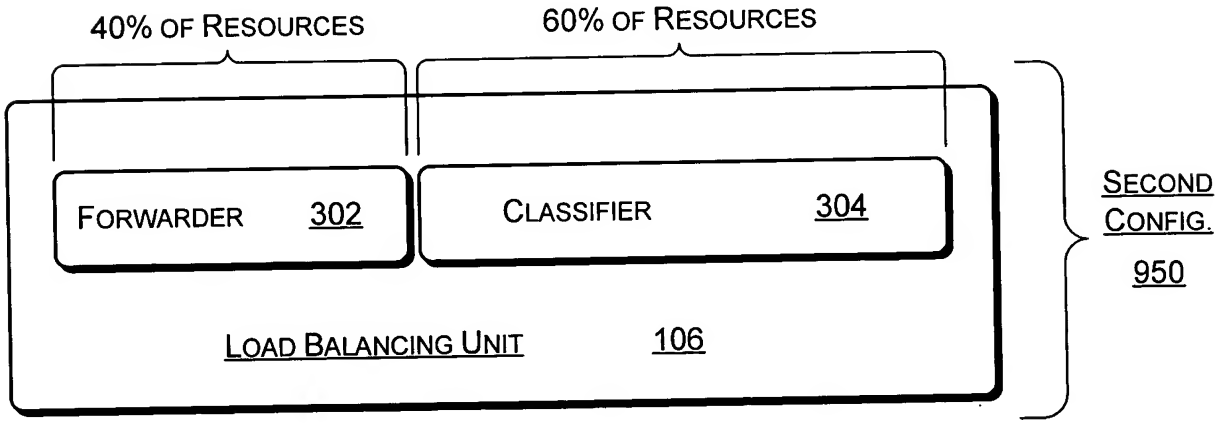

40% OF RESOURCES
60% OF RESOURCES
FORWARDER 302
CLASSIFIER 304
LOAD BALANCING UNIT 106
SECOND CONFIG. 950

FIG. 9B

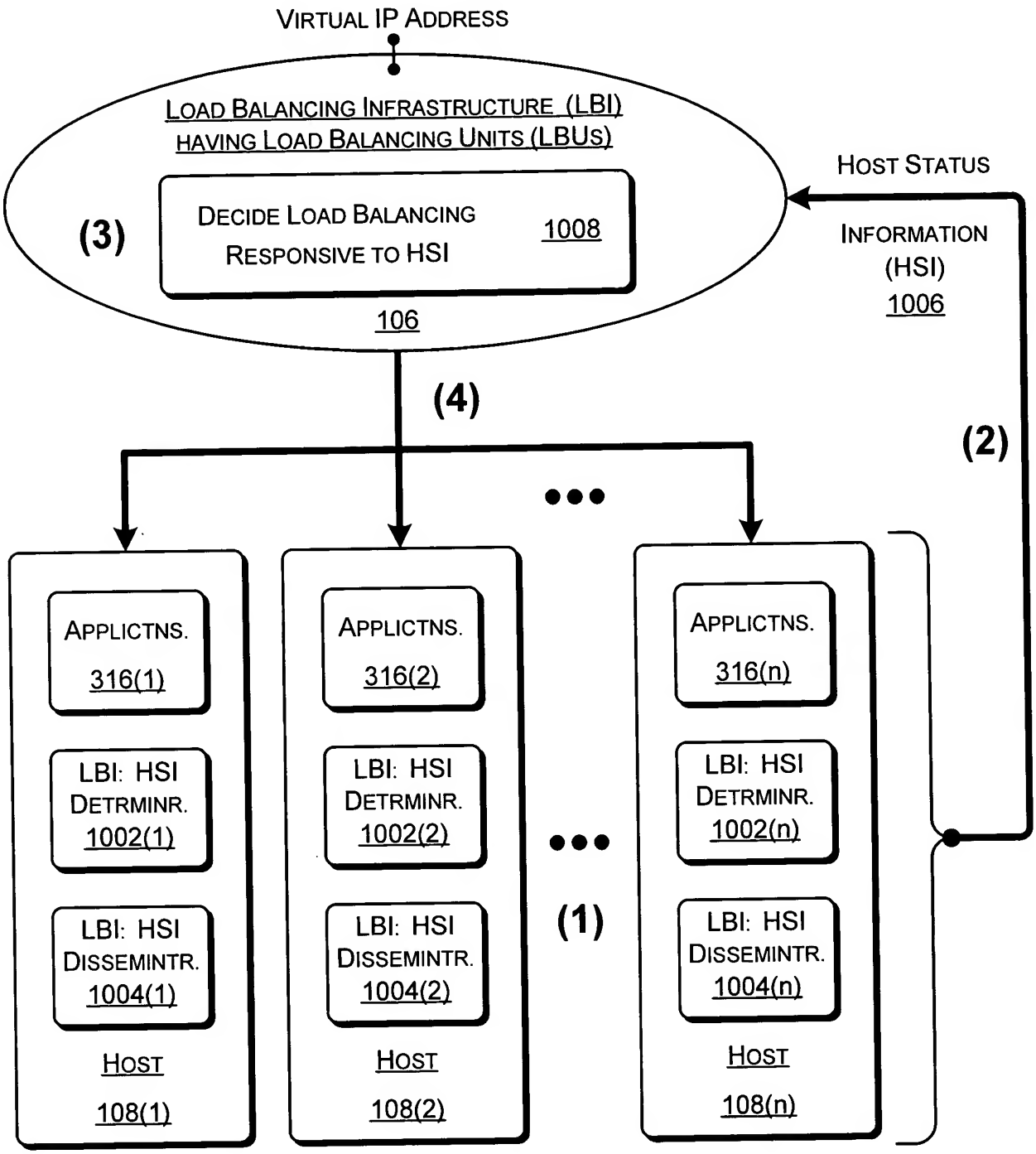

VIRTUAL IP ADDRESS
LOAD BALANCING INFRASTRUCTURE (LBI)
HAVING LOAD BALANCING UNITS (LBUS)
(3)
DECIDE LOAD BALANCING
RESPONSIVE TO HSI
1008
106
HOST STATUS
INFORMATION
(HSI)
1006
(4)
(2)
APPLICTNS.
316(1)
LBI: HSI
DETRMINR.
1002(1)
LBI: HSI
DISSEMINTR.
1004(1)
HOST
108(1)
APPLICTNS.
316(2)
LBI: HSI
DETRMINR.
1002(2)
LBI: HSI
DISSEMINTR.
1004(2)
HOST
108(2)
(1)
APPLICTNS.
316(n)
LBI: HSI
DETRMINR.
1002(n)
LBI: HSI
DISSEMINTR.
1004(n)
HOST
108(n)

FIG. 10

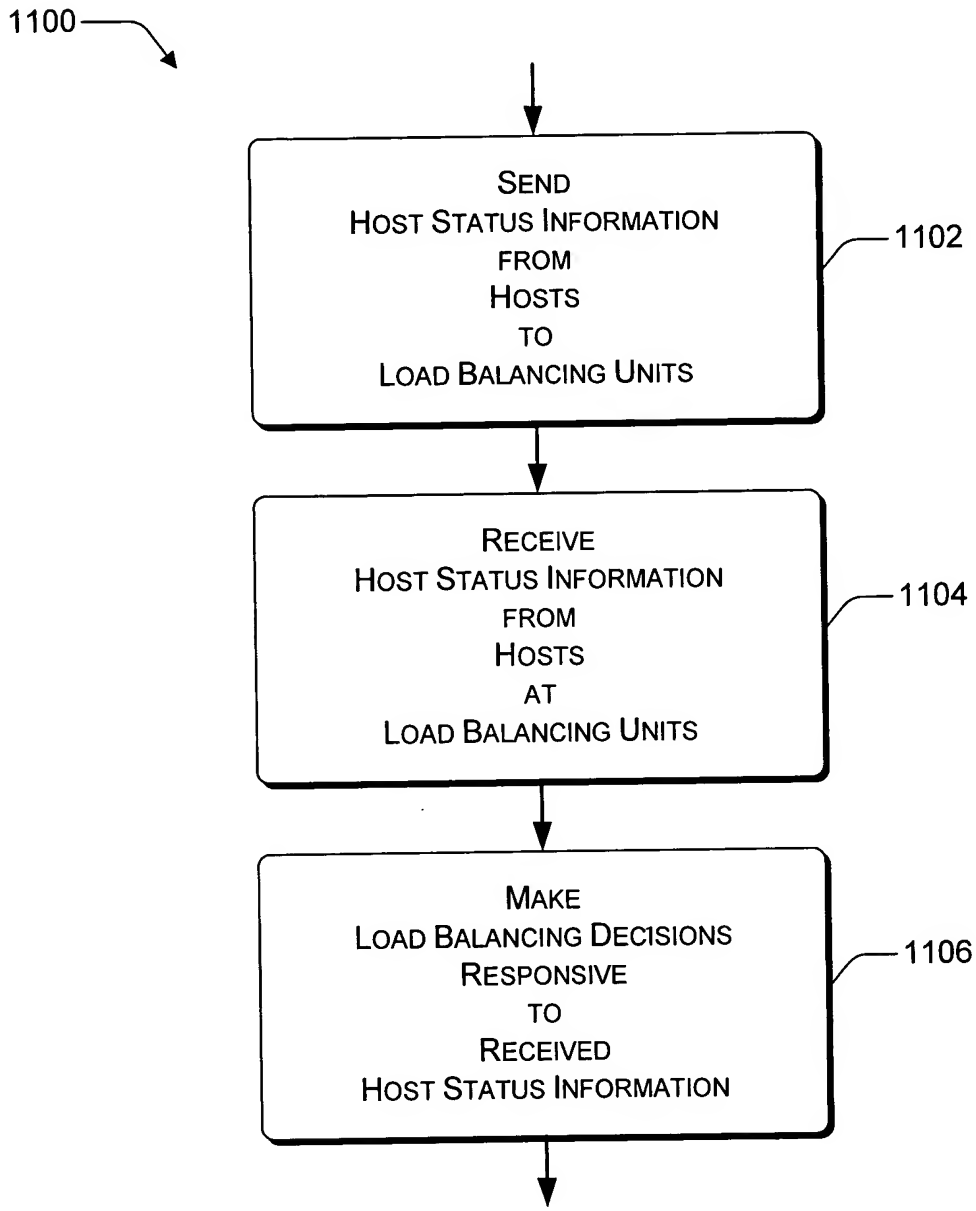

1100
SEND HOST STATUS INFORMATION FROM HOSTS TO LOAD BALANCING UNITS
1102
RECEIVE HOST STATUS INFORMATION FROM HOSTS AT LOAD BALANCING UNITS
1104
MAKE LOAD BALANCING DECISIONS RESPONSIVE TO RECEIVED HOST STATUS INFORMATION
1106

FIG. 11

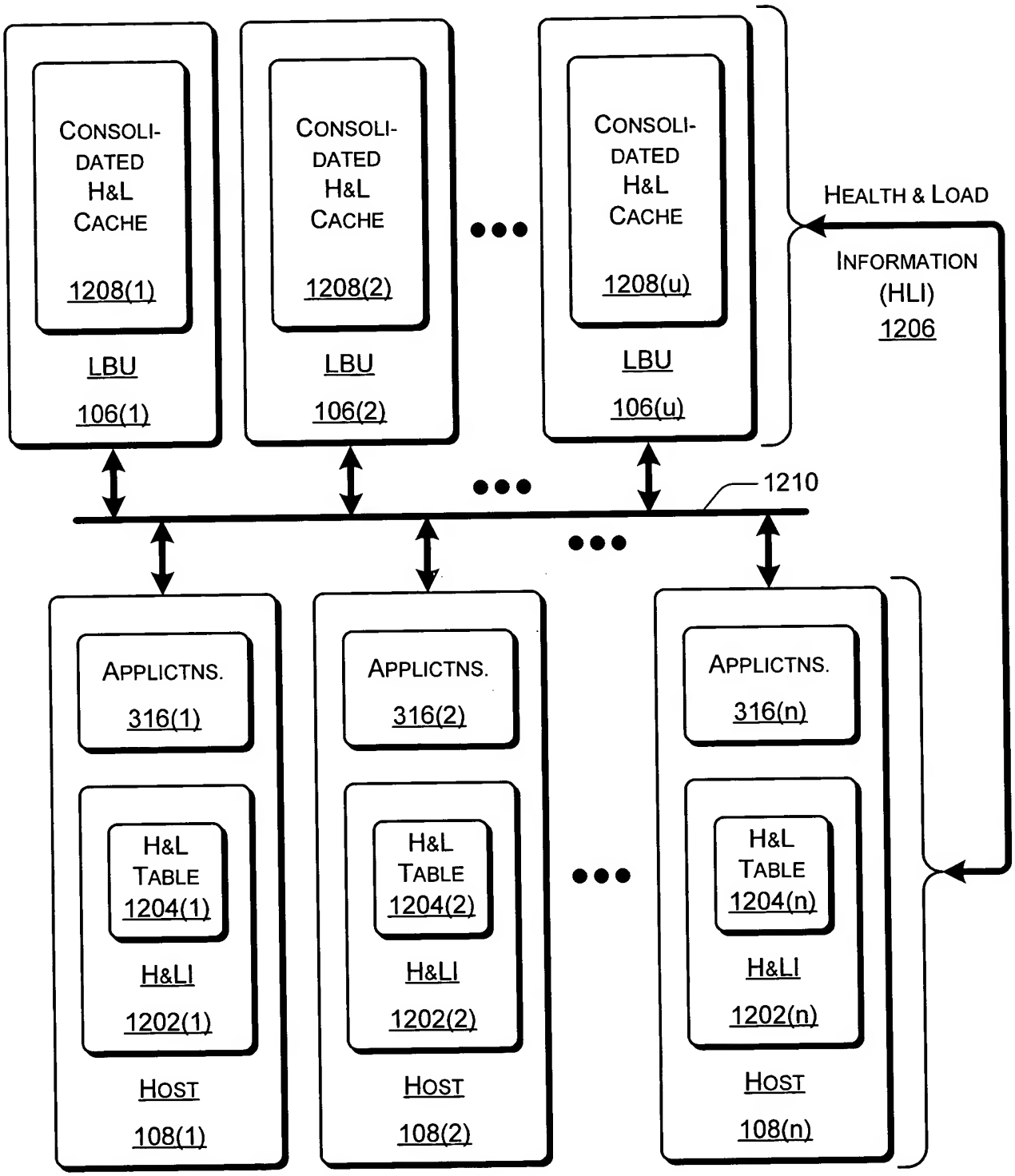

CONSOLI-
DATED
H&L
CACHE
1208(1)
LBU
106(1)
CONSOLI-
DATED
H&L
CACHE
1208(2)
LBU
106(2)
CONSOLI-
DATED
H&L
CACHE
1208(u)
LBU
106(u)
HEALTH & LOAD
INFORMATION
(HLI)
1206
1210
APPLICTNS.
316(1)
H&L
TABLE
1204(1)
H&LI
1202(1)
HOST
108(1)
APPLICTNS.
316(2)
H&L
TABLE
1204(2)
H&LI
1202(2)
HOST
108(2)
APPLICTNS.
316(n)
H&L
TABLE
1204(n)
H&LI
1202(n)
HOST
108(n)

FIG. 12

H&L TABLE		1204
APPLICATION IDENTIFIER (ID) 1302(A)	APPLICATION STATUS CHARACTERIZATION 1302(B)	LOAD BALANCER DIRECTIVE 1302(C)
VIRTUAL IP ADDR. & PORT	APPLICATION HEALTH	TARGET LOAD BALANCING STATE
PHYSICAL IP ADDR. & PORT	APPLICATION LOAD	
PROTOCOL	APPLICATION CAPACITY	CURRENT LOAD BALANCING STATE
PROTOCOL-SPECIFIC INFO.		

FIG. 13A

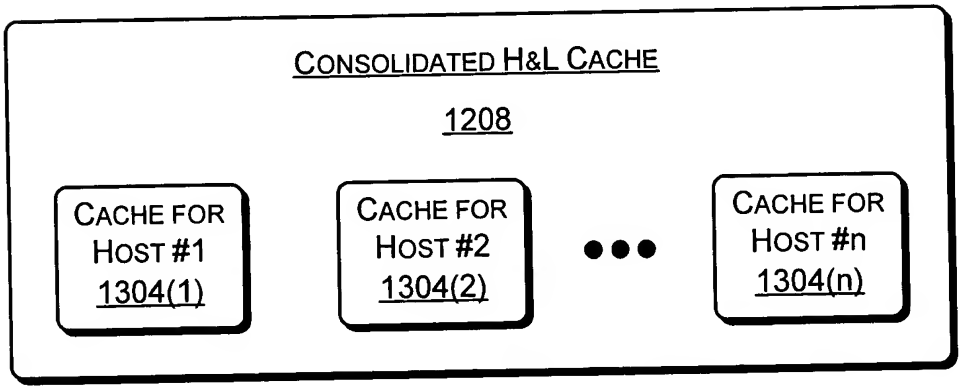


FIG. 13B

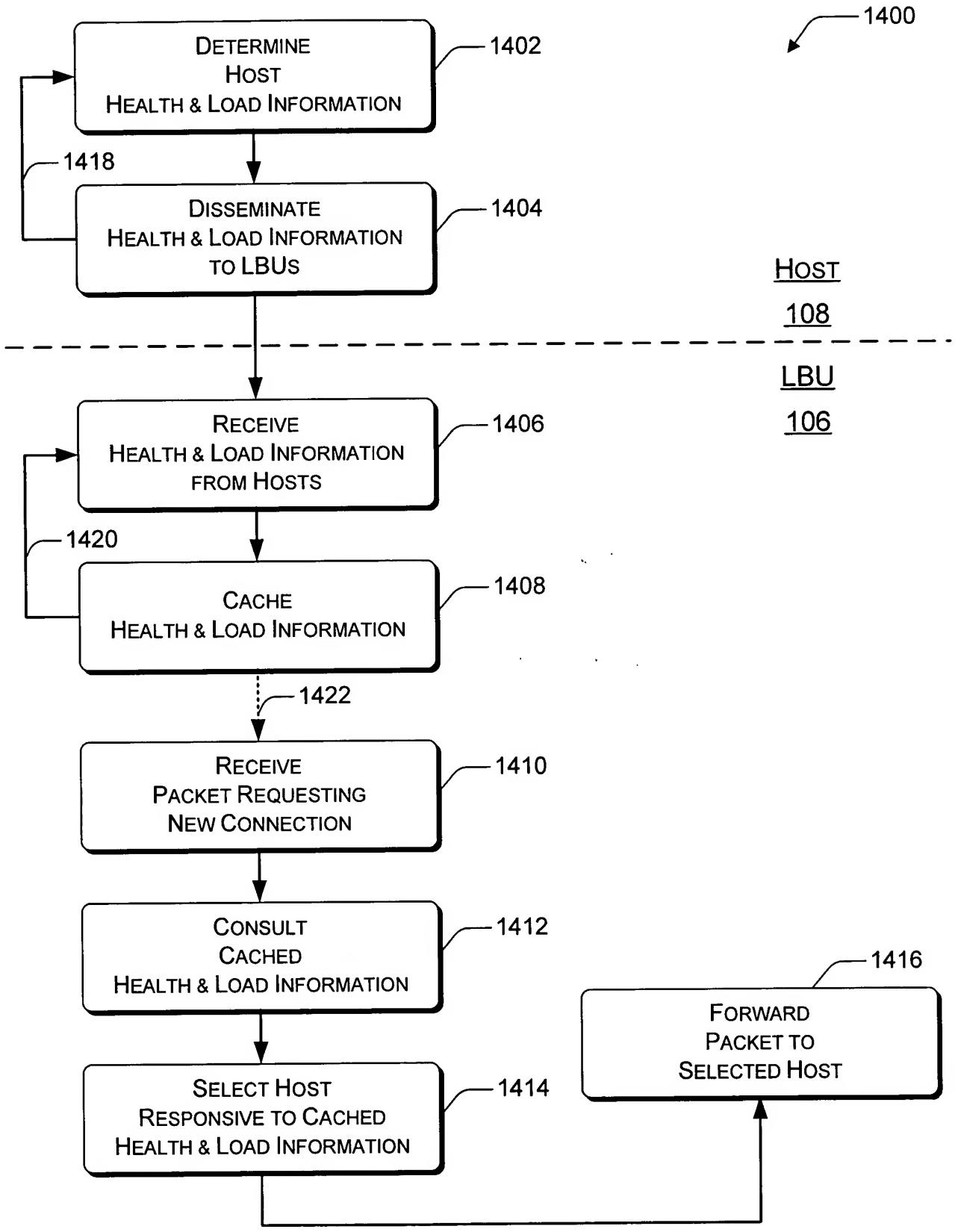

1400
DETERMINE HOST HEALTH & LOAD INFORMATION
1402
1418
DISSEMINATE HEALTH & LOAD INFORMATION TO LBUs
1404
HOST 108
LBU 106
RECEIVE HEALTH & LOAD INFORMATION FROM HOSTS
1406
1420
CACHE HEALTH & LOAD INFORMATION
1408
1422
RECEIVE PACKET REQUESTING NEW CONNECTION
1410
CONSULT CACHED HEALTH & LOAD INFORMATION
1412
SELECT HOST RESPONSIVE TO CACHED HEALTH & LOAD INFORMATION
1414
FORWARD PACKET TO SELECTED HOST
1416

FIG. 14

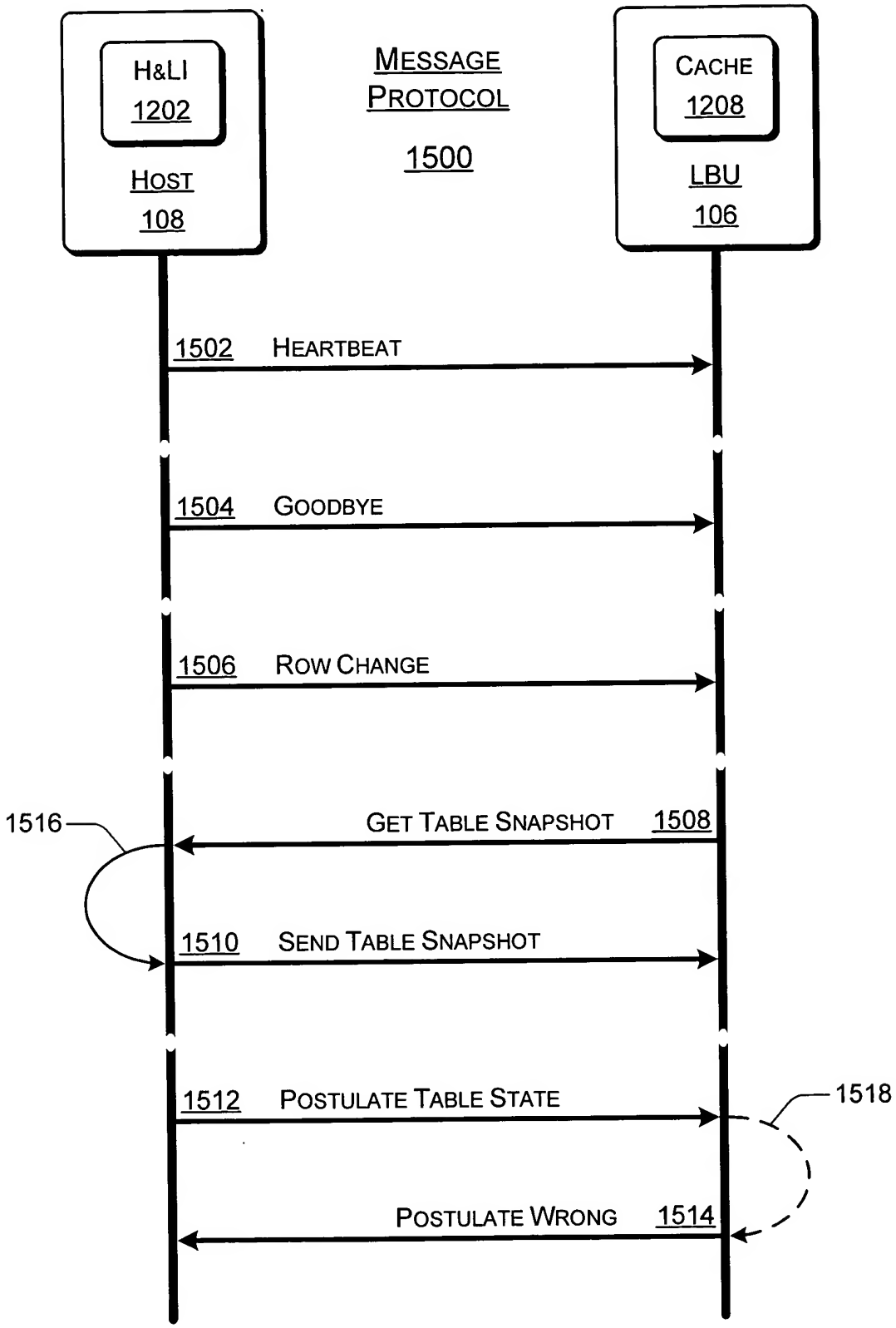

H&LI
1202
HOST
108
MESSAGE
PROTOCOL
1500
CACHE
1208
LBU
106
1502 HEARTBEAT
1504 GOODBYE
1506 ROW CHANGE
1516
GET TABLE SNAPSHOT 1508
1510 SEND TABLE SNAPSHOT
1512 POSTULATE TABLE STATE
1518
POSTULATE WRONG 1514

FIG. 15

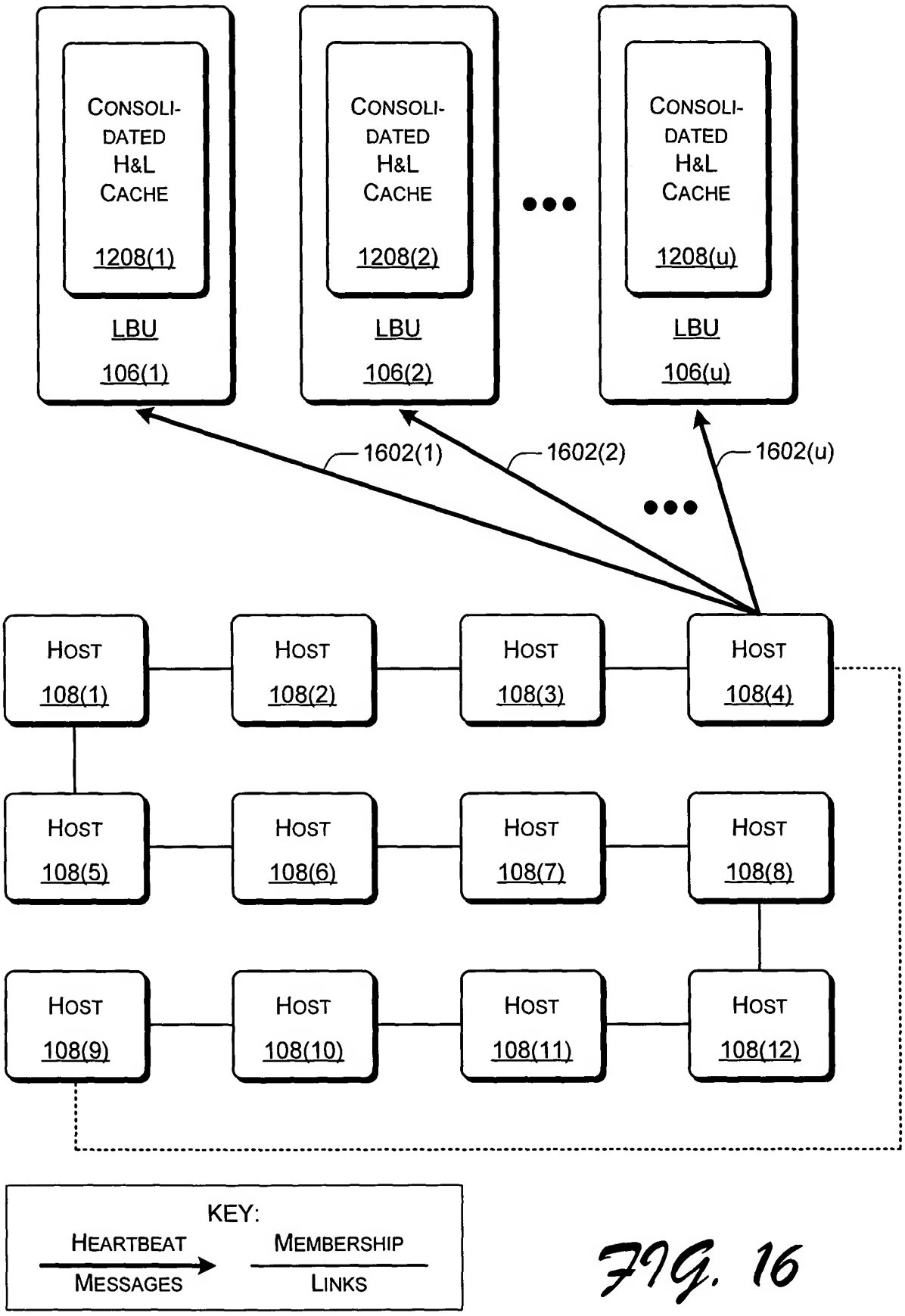

CONSOLI-
DATED
H&L
CACHE
1208(1)
LBU
106(1)
CONSOLI-
DATED
H&L
CACHE
1208(2)
LBU
106(2)
CONSOLI-
DATED
H&L
CACHE
1208(u)
LBU
106(u)
1602(1)
1602(2)
1602(u)
HOST
108(1)
HOST
108(2)
HOST
108(3)
HOST
108(4)
HOST
108(5)
HOST
108(6)
HOST
108(7)
HOST
108(8)
HOST
108(9)
HOST
108(10)
HOST
108(11)
HOST
108(12)
KEY:
HEARTBEAT
MESSAGES
MEMBERSHIP
LINKS

FIG. 16

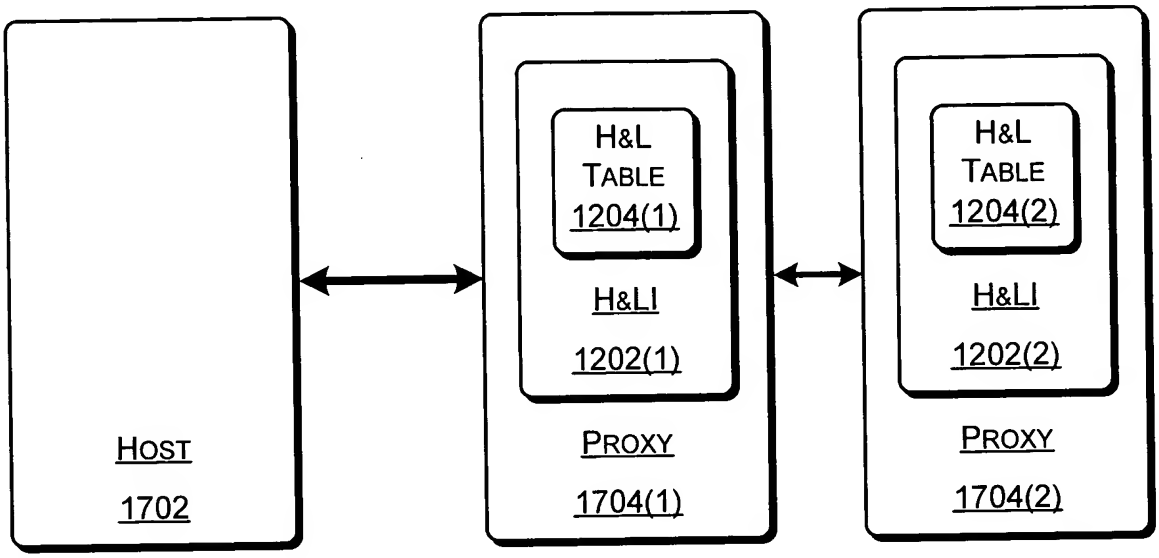


FIG. 17A

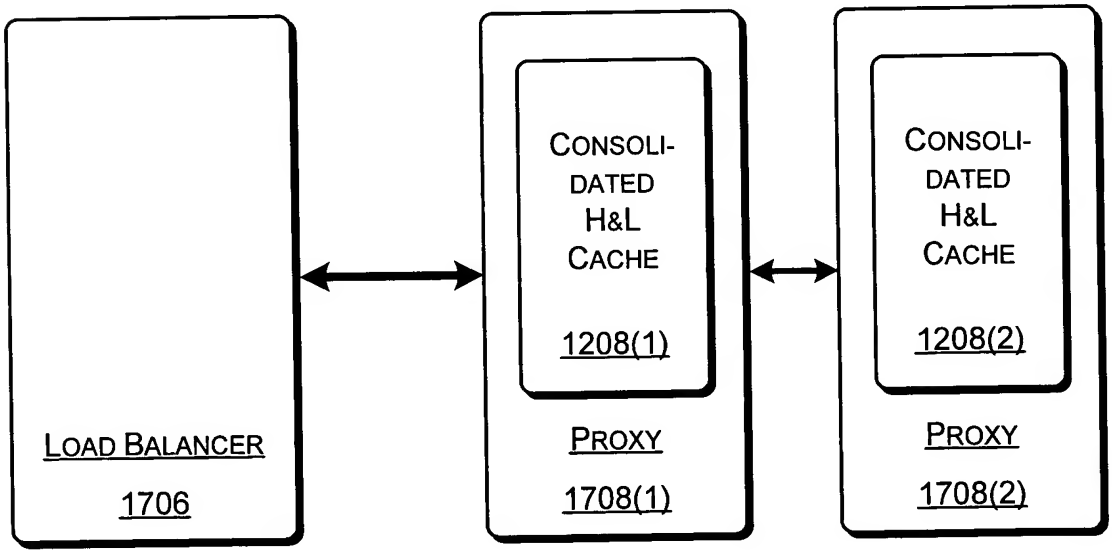


FIG. 17B

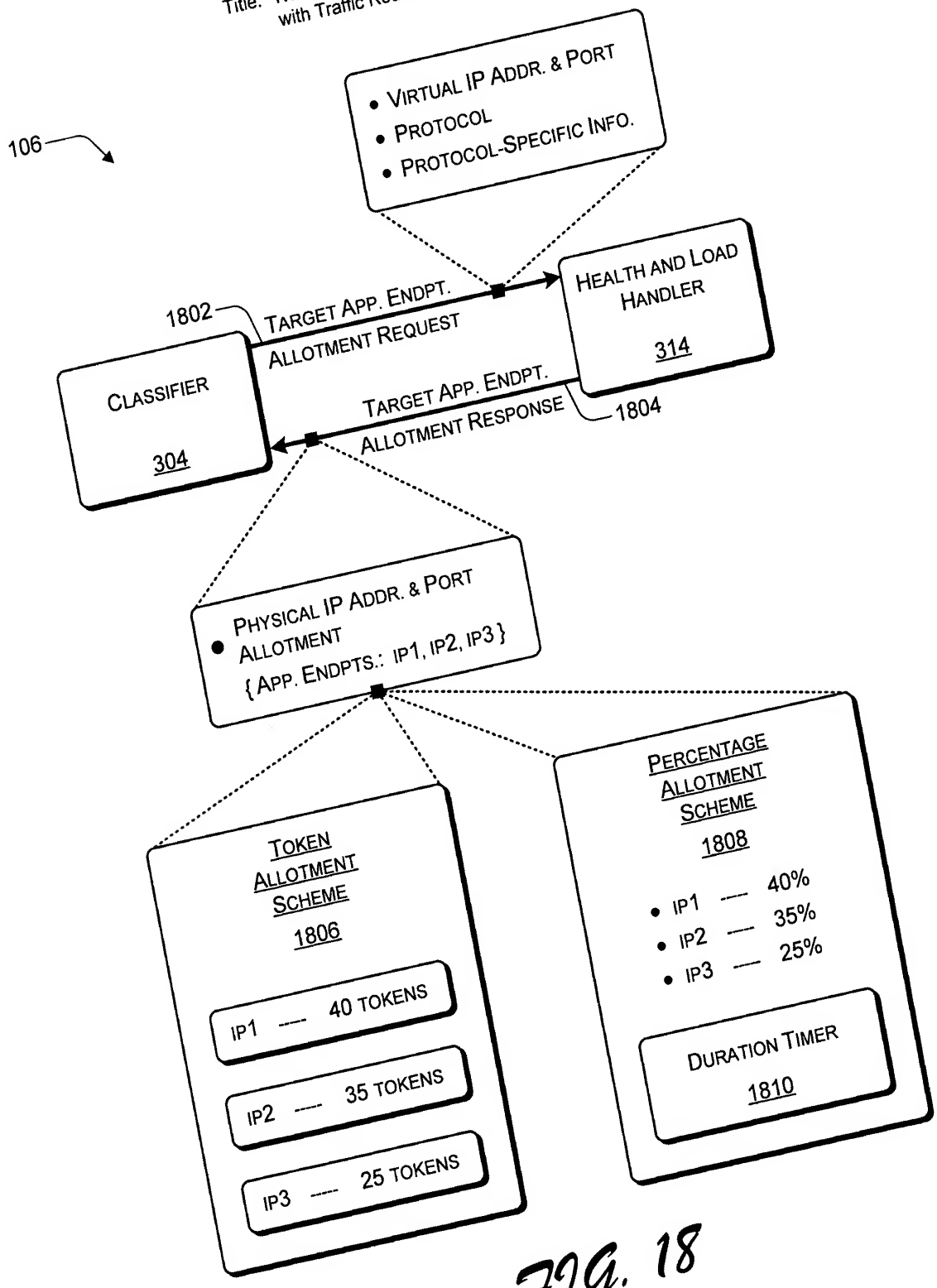

106
• VIRTUAL IP ADDR. & PORT
• PROTOCOL
• PROTOCOL-SPECIFIC INFO.
HEALTH AND LOAD HANDLER
314
1802
TARGET APP. ENDPT.
ALLOTMENT REQUEST
TARGET APP. ENDPT.
ALLOTMENT RESPONSE
1804
CLASSIFIER
304
• PHYSICAL IP ADDR. & PORT ALLOTMENT
{APP. ENDPTS.: IP1, IP2, IP3}
TOKEN ALLOTMENT SCHEME
1806
IP1 — 40 TOKENS
IP2 — 35 TOKENS
IP3 — 25 TOKENS
PERCENTAGE ALLOTMENT SCHEME
1808
• IP1 — 40%
• IP2 — 35%
• IP3 — 25%
DURATION TIMER
1810

FIG. 18

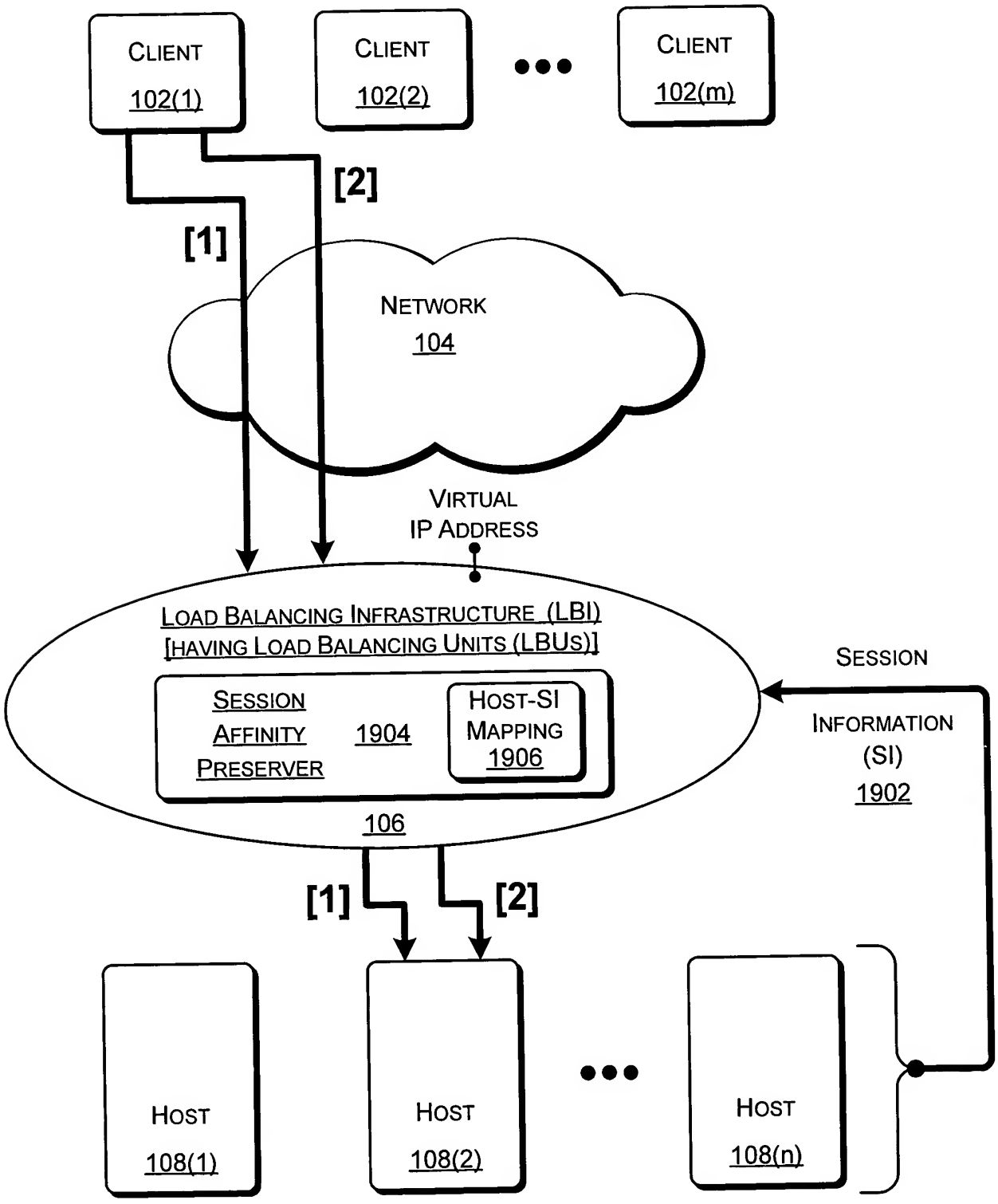

CLIENT
102(1)
CLIENT
102(2)
CLIENT
102(m)
[2]
[1]
NETWORK
104
VIRTUAL
IP ADDRESS
LOAD BALANCING INFRASTRUCTURE (LBI)
[HAVING LOAD BALANCING UNITS (LBUs)]
SESSION
AFFINITY
PRESERVER
1904
HOST-SI
MAPPING
1906
106
SESSION
INFORMATION
(SI)
1902
[1]
[2]
HOST
108(1)
HOST
108(2)
HOST
108(n)

FIG. 19

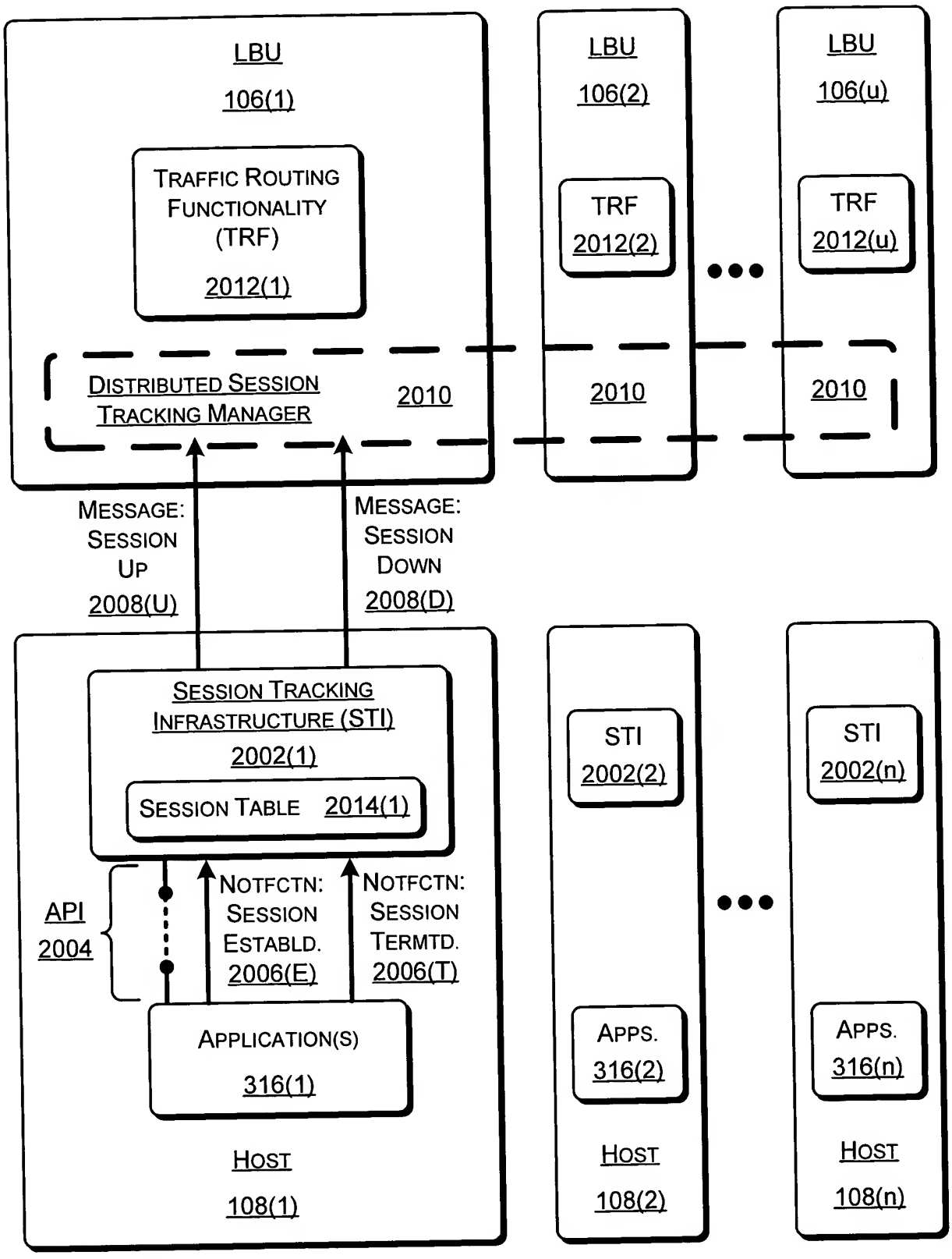

LBU
106(1)
TRAFFIC ROUTING FUNCTIONALITY (TRF)
2012(1)
DISTRIBUTED SESSION TRACKING MANAGER
2010
LBU
106(2)
TRF
2012(2)
2010
LBU
106(u)
TRF
2012(u)
2010
MESSAGE: SESSION UP
2008(U)
MESSAGE: SESSION DOWN
2008(D)
SESSION TRACKING INFRASTRUCTURE (STI)
2002(1)
SESSION TABLE 2014(1)
API
2004
NOTFCTN: SESSION ESTABLD.
2006(E)
NOTFCTN: SESSION TERMTD.
2006(T)
APPLICATION(S)
316(1)
HOST
108(1)
STI
2002(2)
APPS.
316(2)
HOST
108(2)
STI
2002(n)
APPS.
316(n)
HOST
108(n)

FIG. 20

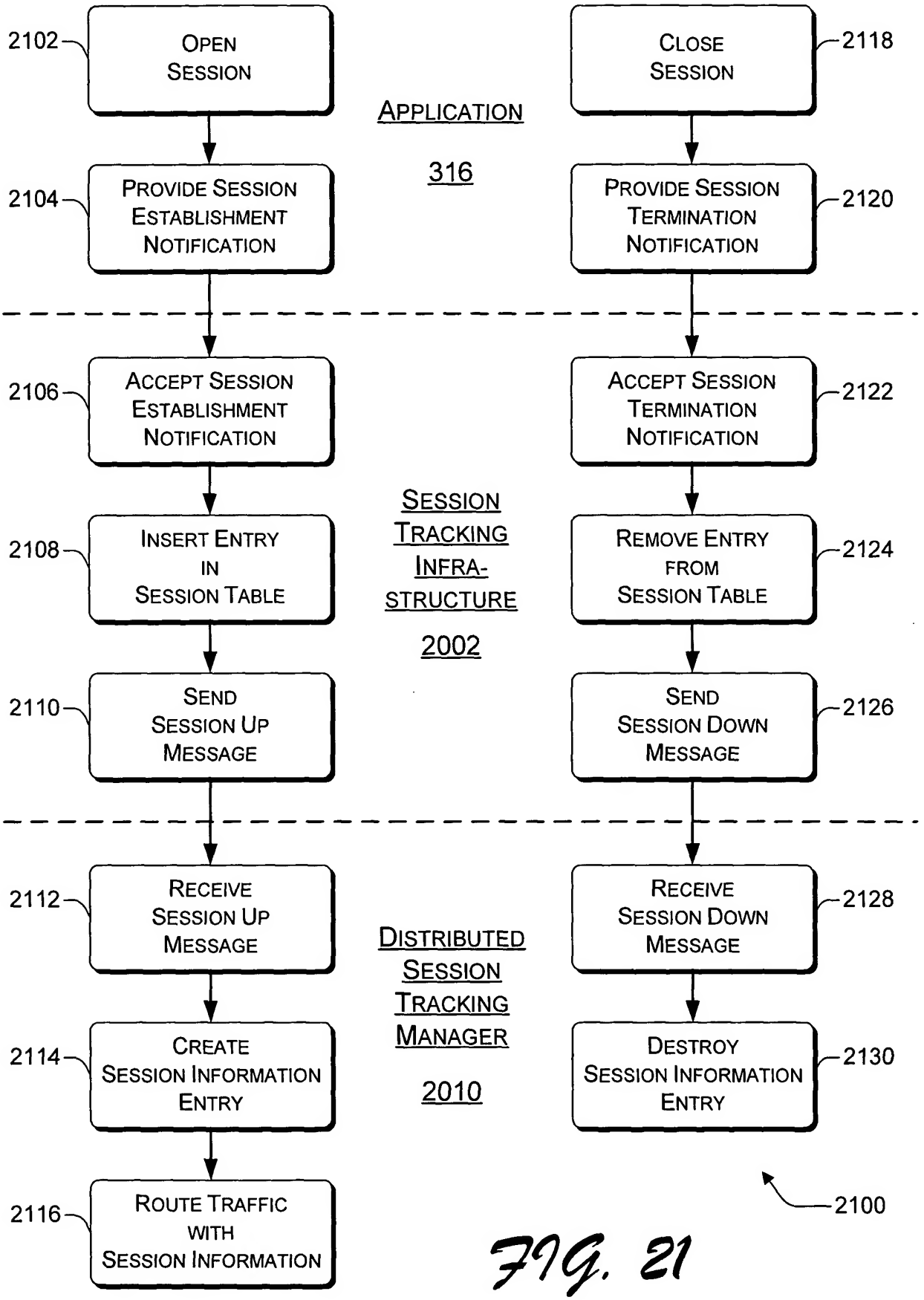

2102
OPEN SESSION
2104
PROVIDE SESSION ESTABLISHMENT NOTIFICATION
2106
ACCEPT SESSION ESTABLISHMENT NOTIFICATION
2108
INSERT ENTRY IN SESSION TABLE
2110
SEND SESSION UP MESSAGE
2112
RECEIVE SESSION UP MESSAGE
2114
CREATE SESSION INFORMATION ENTRY
2116
ROUTE TRAFFIC WITH SESSION INFORMATION
APPLICATION 316
SESSION TRACKING INFRA-STRUCTURE 2002
DISTRIBUTED SESSION TRACKING MANAGER 2010
2118
CLOSE SESSION
2120
PROVIDE SESSION TERMINATION NOTIFICATION
2122
ACCEPT SESSION TERMINATION NOTIFICATION
2124
REMOVE ENTRY FROM SESSION TABLE
2126
SEND SESSION DOWN MESSAGE
2128
RECEIVE SESSION DOWN MESSAGE
2130
DESTROY SESSION INFORMATION ENTRY
2100

FIG. 21

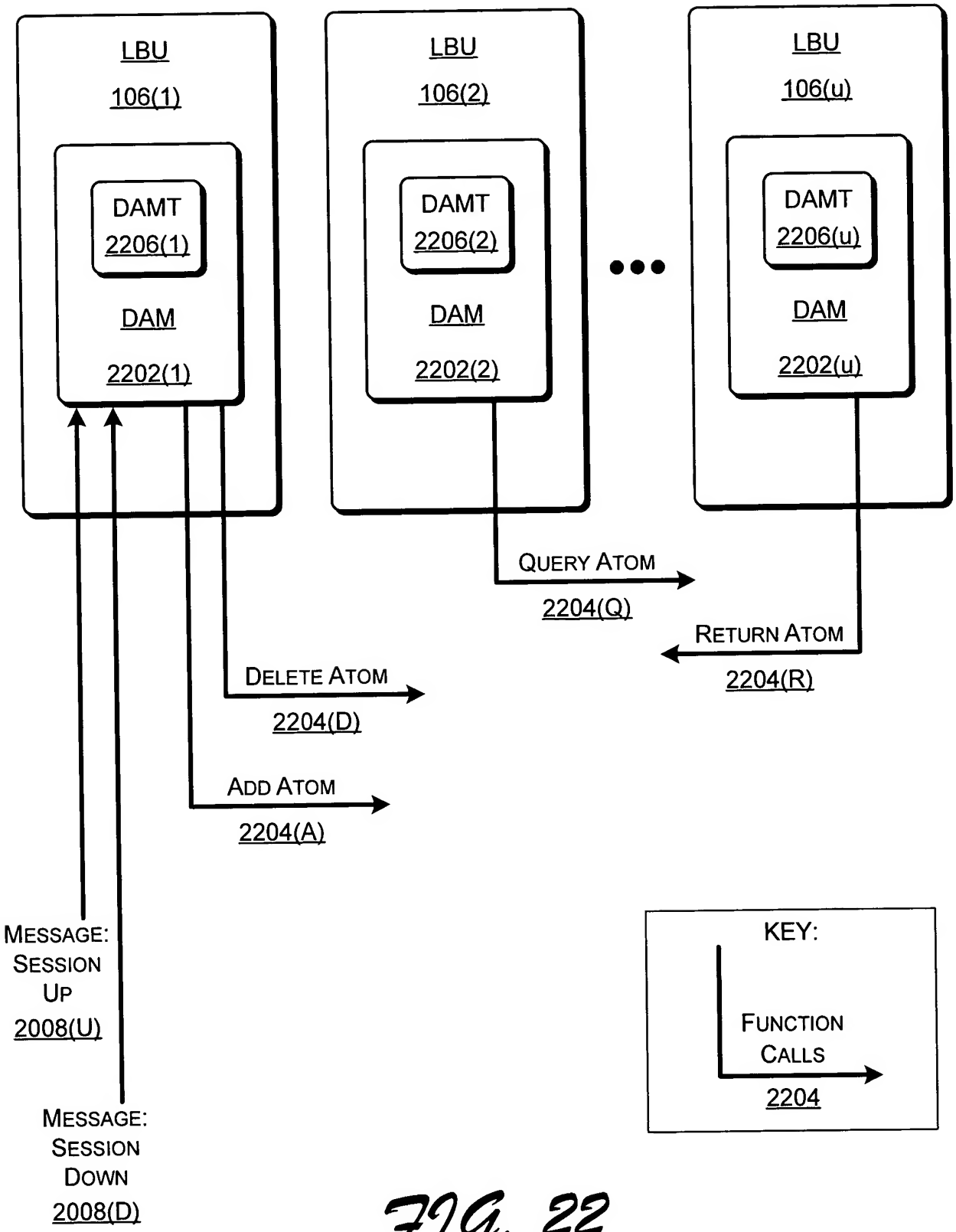

LBU
106(1)
DAMT
2206(1)
DAM
2202(1)
LBU
106(2)
DAMT
2206(2)
DAM
2202(2)
LBU
106(u)
DAMT
2206(u)
DAM
2202(u)
QUERY ATOM
2204(Q)
RETURN ATOM
2204(R)
DELETE ATOM
2204(D)
ADD ATOM
2204(A)
MESSAGE:
SESSION
UP
2008(U)
MESSAGE:
SESSION
DOWN
2008(D)
KEY:
FUNCTION
CALLS
2204

FIG. 22

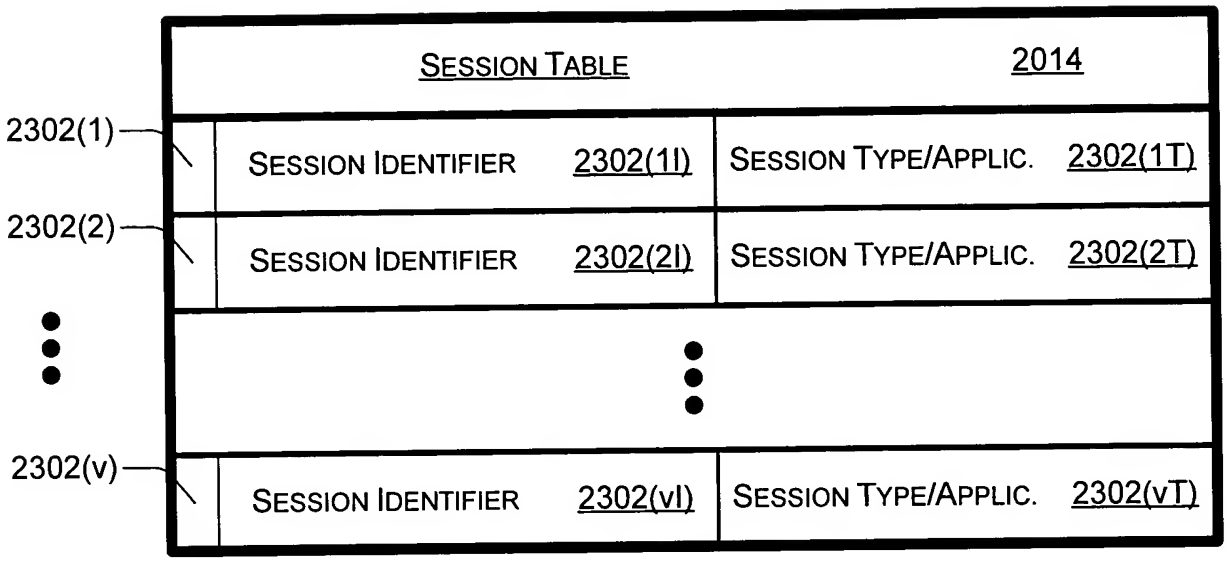


FIG. 23A

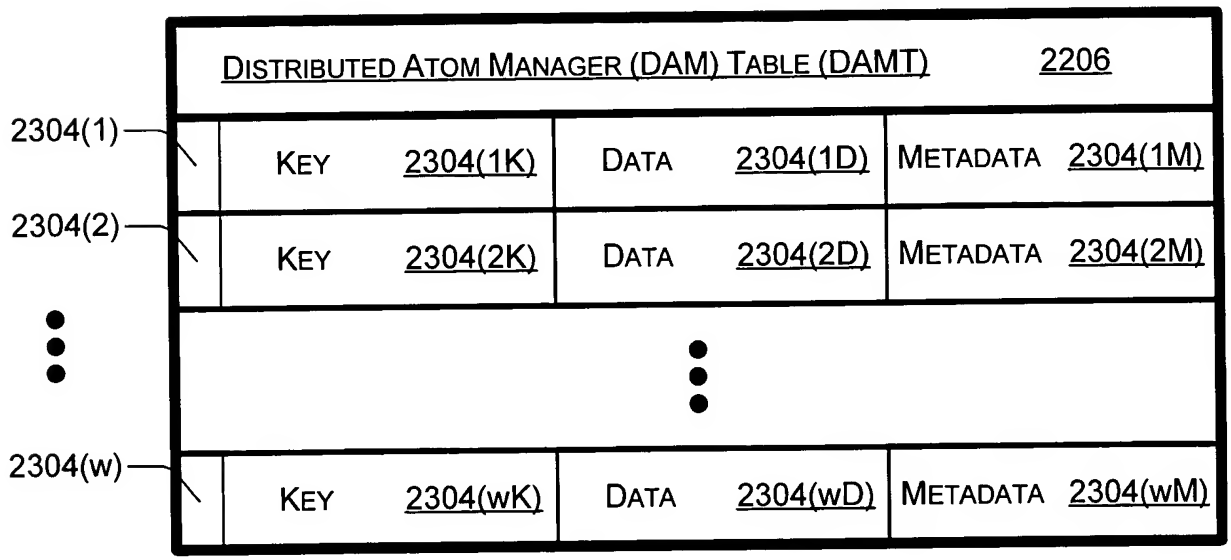


FIG. 23B

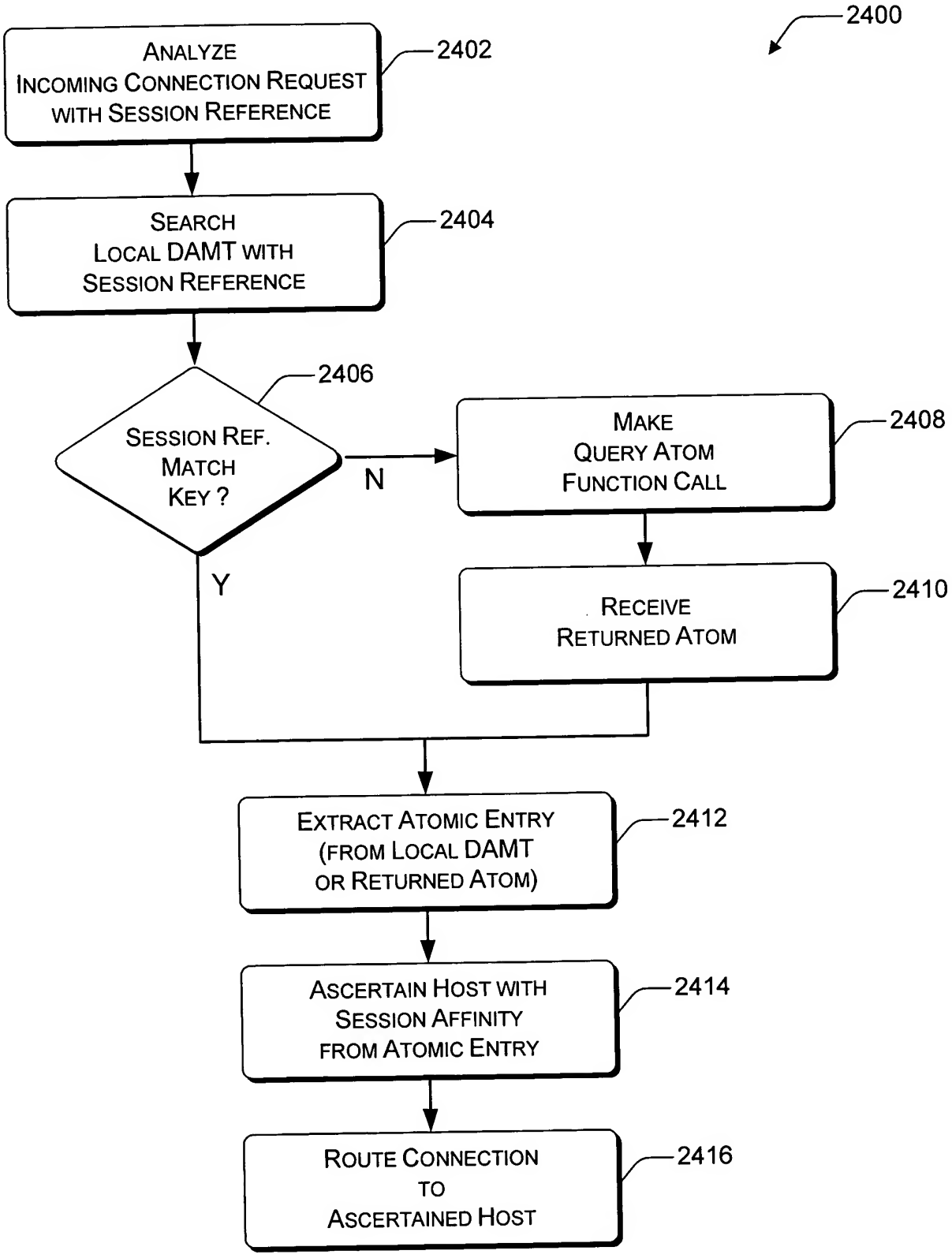

2400
ANALYZE INCOMING CONNECTION REQUEST WITH SESSION REFERENCE
2402
SEARCH LOCAL DAMT WITH SESSION REFERENCE
2404
SESSION REF. MATCH KEY ?
2406
N
MAKE QUERY ATOM FUNCTION CALL
2408
Y
RECEIVE RETURNED ATOM
2410
EXTRACT ATOMIC ENTRY (FROM LOCAL DAMT OR RETURNED ATOM)
2412
ASCERTAIN HOST WITH SESSION AFFINITY FROM ATOMIC ENTRY
2414
ROUTE CONNECTION TO ASCERTAINED HOST
2416

FIG. 24

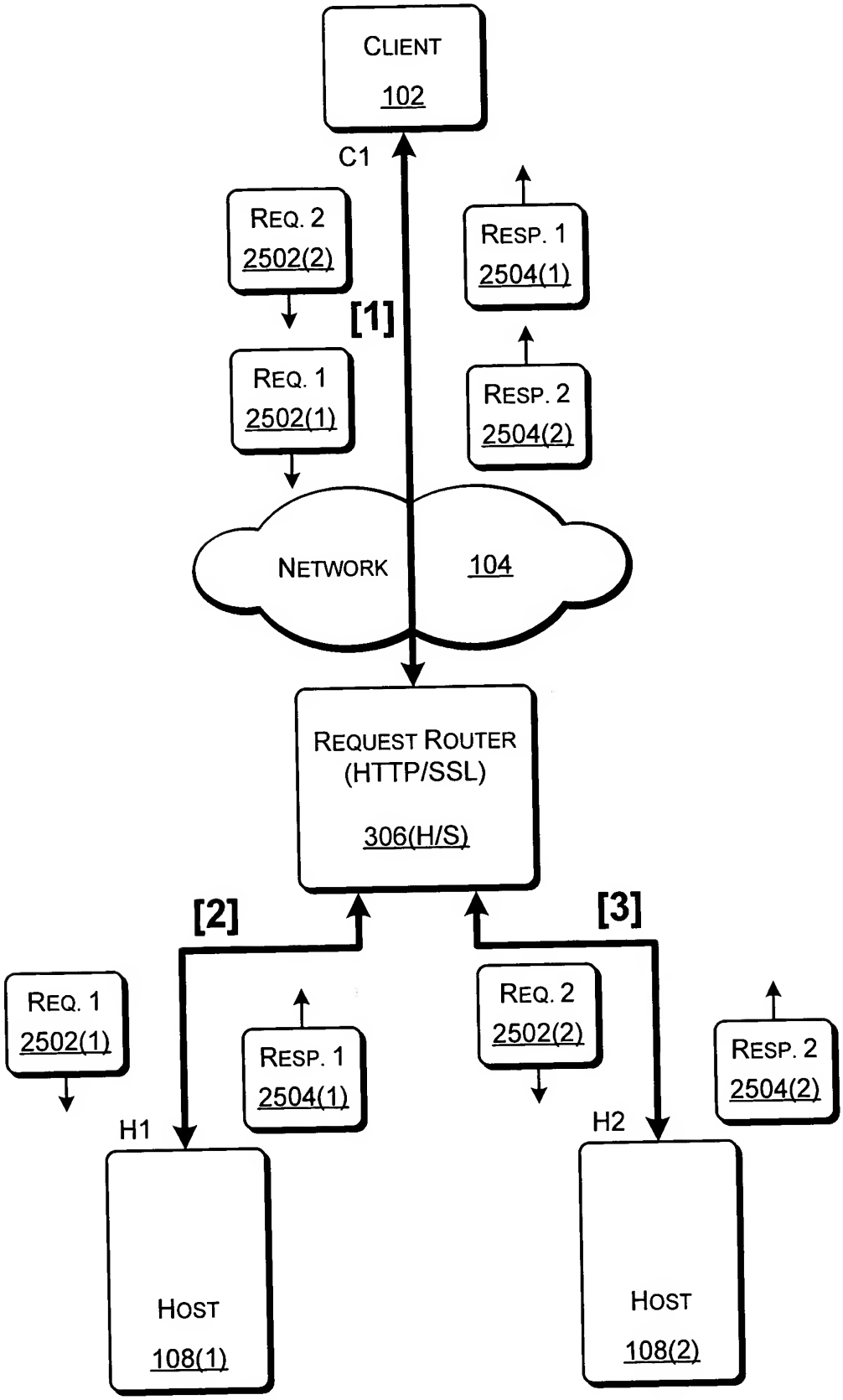

CLIENT
102
C1
REQ. 2
2502(2)
[1]
REQ. 1
2502(1)
RESP. 1
2504(1)
RESP. 2
2504(2)
NETWORK
104
REQUEST ROUTER
(HTTP/SSL)
306(H/S)
[2]
[3]
REQ. 1
2502(1)
RESP. 1
2504(1)
REQ. 2
2502(2)
RESP. 2
2504(2)
H1
H2
HOST
108(1)
HOST
108(2)

FIG. 25

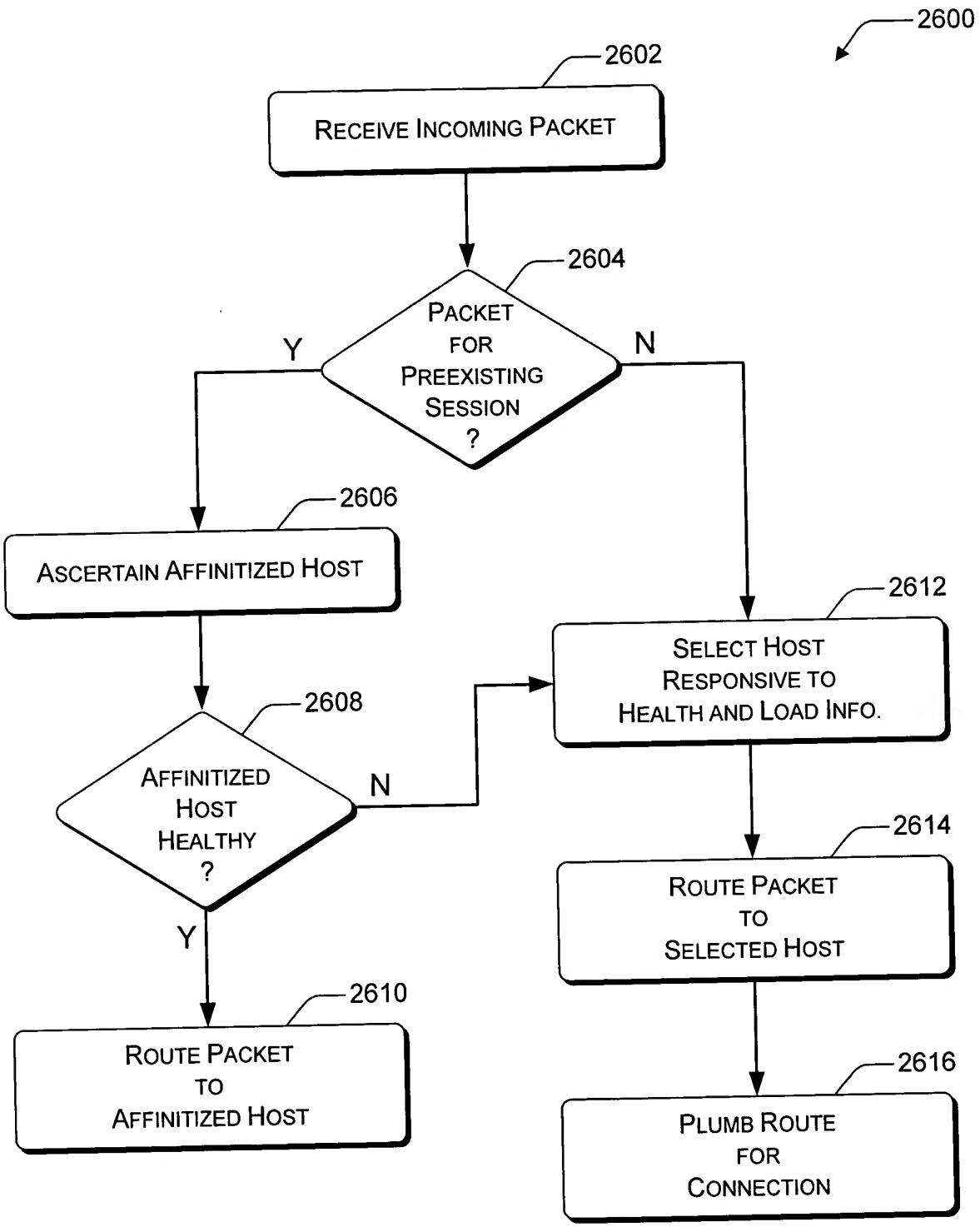

2600
2602
RECEIVE INCOMING PACKET
2604
PACKET FOR PREEXISTING SESSION ?
Y
N
2606
ASCERTAIN AFFINITIZED HOST
2608
AFFINITIZED HOST HEALTHY ?
N
Y
2610
ROUTE PACKET TO AFFINITIZED HOST
2612
SELECT HOST RESPONSIVE TO HEALTH AND LOAD INFO.
2614
ROUTE PACKET TO SELECTED HOST
2616
PLUMB ROUTE FOR CONNECTION

FIG. 26

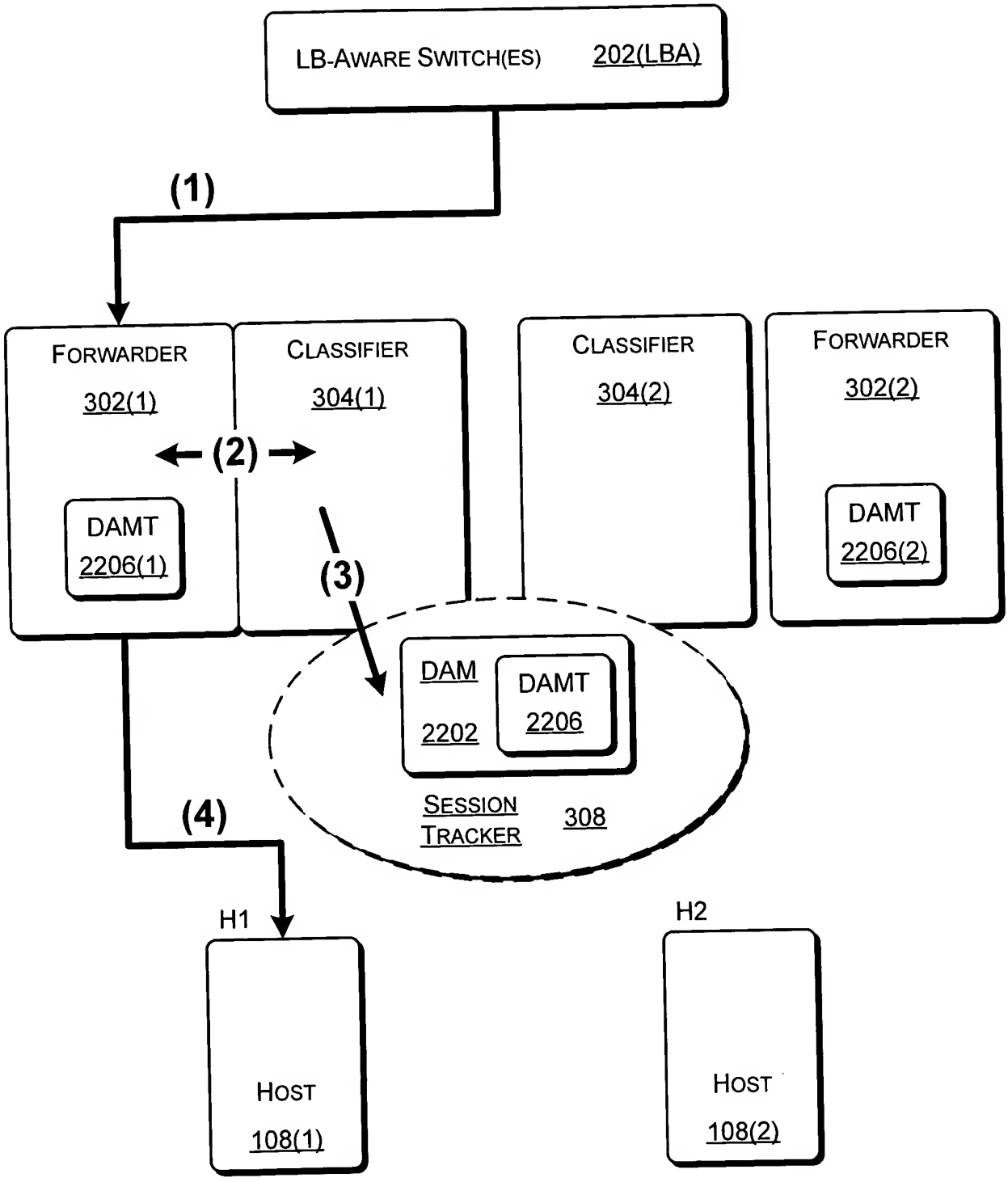

LB-AWARE SWITCH(ES) 202(LBA)
(1)
FORWARDER
302(1)
CLASSIFIER
304(1)
CLASSIFIER
304(2)
FORWARDER
302(2)
(2)
DAMT
2206(1)
(3)
DAMT
2206(2)
DAM
2202
DAMT
2206
SESSION
TRACKER
308
(4)
H1
H2
HOST
108(1)
HOST
108(2)

FIG. 27

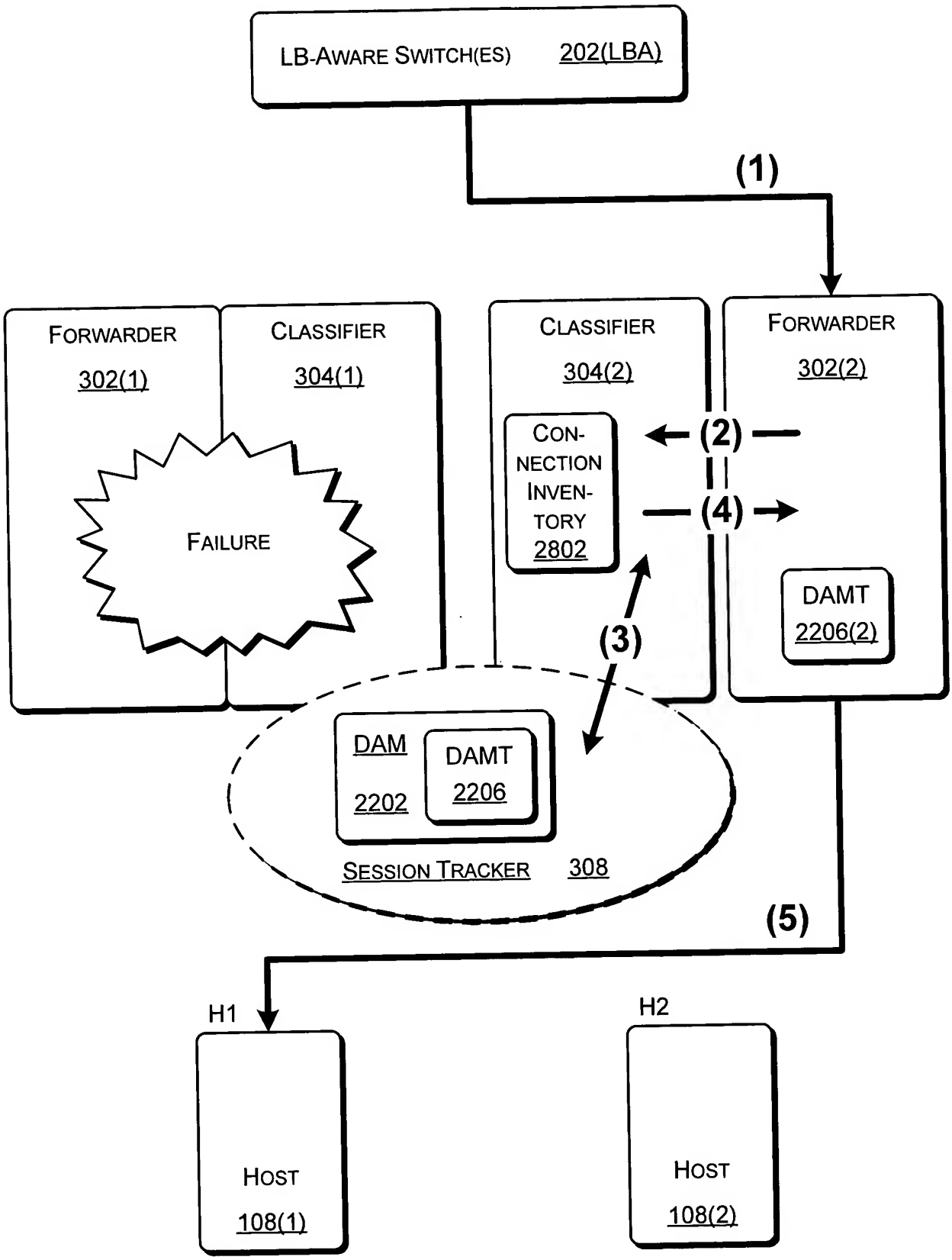

LB-AWARE SWITCH(ES) 202(LBA)
(1)
FORWARDER 302(1)
CLASSIFIER 304(1)
FAILURE
CLASSIFIER 304(2)
FORWARDER 302(2)
CON-NECTION INVEN-TORY 2802
(2)
(4)
DAMT 2206(2)
(3)
DAM 2202
DAMT 2206
SESSION TRACKER 308
(5)
H1
H2
HOST 108(1)
HOST 108(2)

FIG. 28

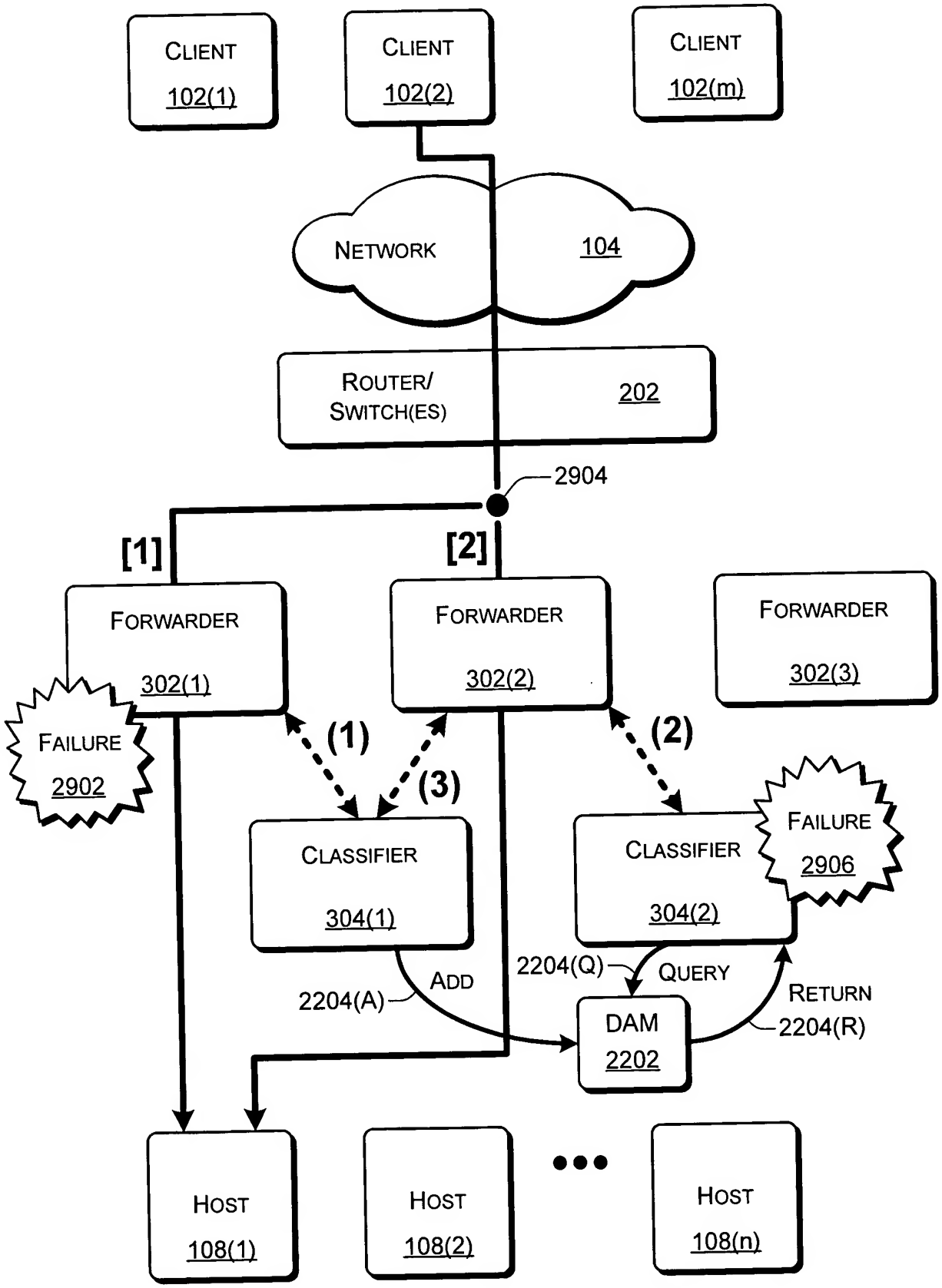

CLIENT
102(1)
CLIENT
102(2)
CLIENT
102(m)
NETWORK
104
ROUTER/
SWITCH(ES)
202
2904
[1]
[2]
FORWARDER
302(1)
FORWARDER
302(2)
FORWARDER
302(3)
FAILURE
2902
(1)
(2)
(3)
CLASSIFIER
304(1)
CLASSIFIER
304(2)
FAILURE
2906
2204(Q)
QUERY
ADD
2204(A)
RETURN
2204(R)
DAM
2202
HOST
108(1)
HOST
108(2)
HOST
108(n)

FIG. 29

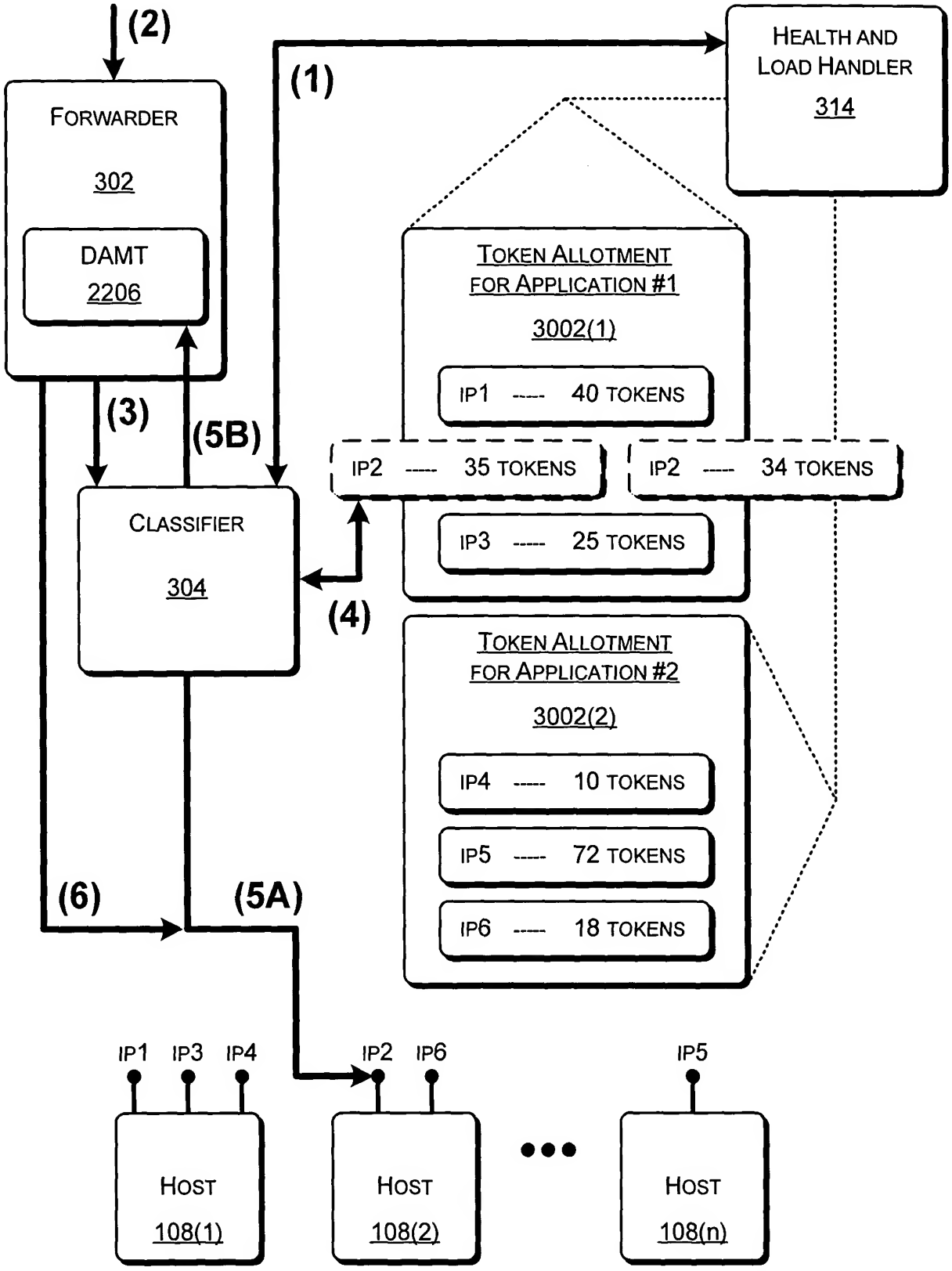

(2)
(1)
HEALTH AND LOAD HANDLER
314
FORWARDER
302
DAMT
2206
TOKEN ALLOTMENT FOR APPLICATION #1
3002(1)
IP1 ----- 40 TOKENS
IP2 ----- 35 TOKENS
IP2 ----- 34 TOKENS
IP3 ----- 25 TOKENS
(3)
(5B)
CLASSIFIER
304
(4)
TOKEN ALLOTMENT FOR APPLICATION #2
3002(2)
IP4 ----- 10 TOKENS
IP5 ----- 72 TOKENS
IP6 ----- 18 TOKENS
(6)
(5A)
IP1 IP3 IP4
IP2 IP6
IP5
HOST 108(1)
HOST 108(2)
HOST 108(n)

FIG. 30

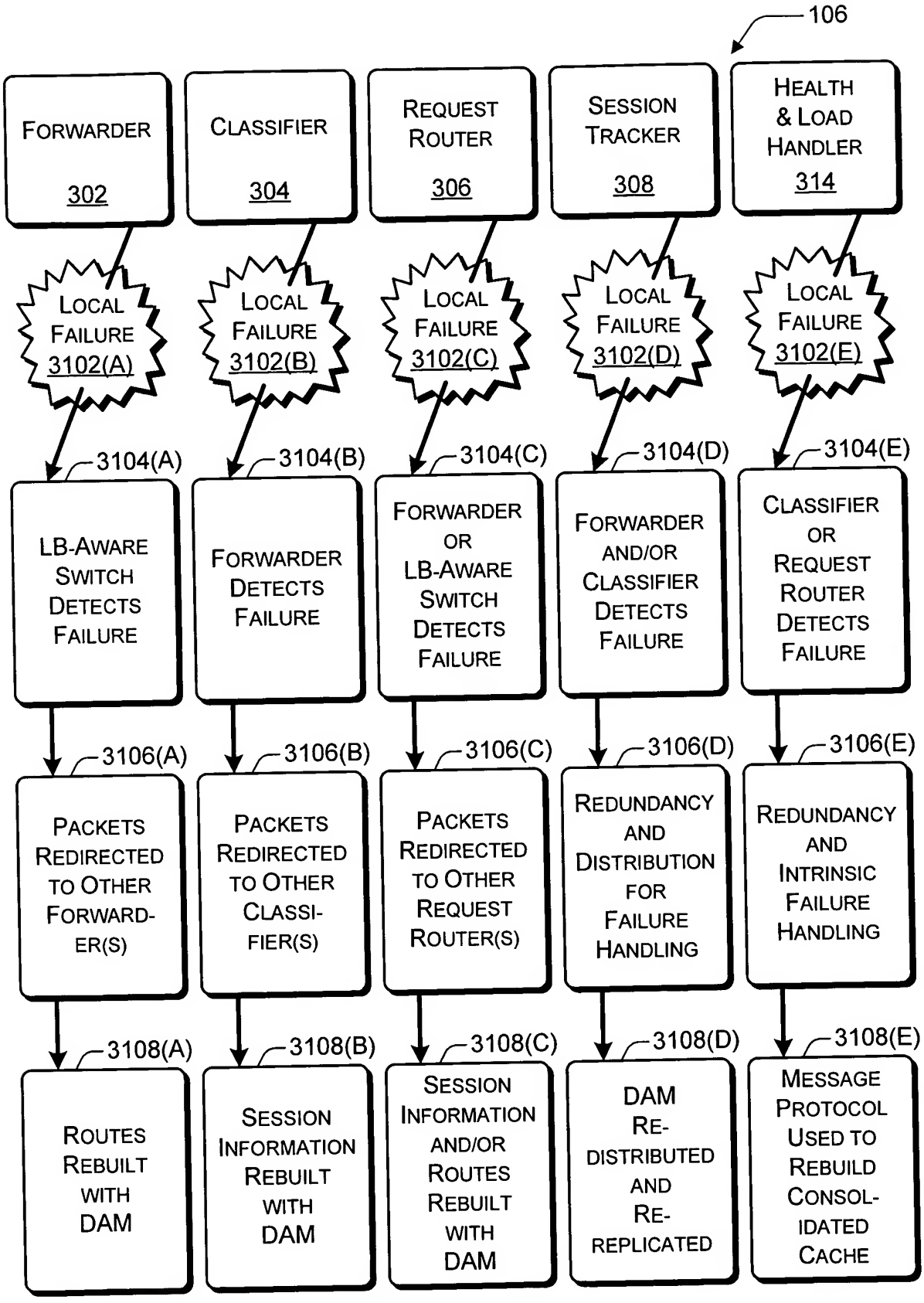

106
FORWARDER 302
CLASSIFIER 304
REQUEST ROUTER 306
SESSION TRACKER 308
HEALTH & LOAD HANDLER 314
LOCAL FAILURE 3102(A)
LOCAL FAILURE 3102(B)
LOCAL FAILURE 3102(C)
LOCAL FAILURE 3102(D)
LOCAL FAILURE 3102(E)
3104(A)
3104(B)
3104(C)
3104(D)
3104(E)
LB-AWARE SWITCH DETECTS FAILURE
FORWARDER DETECTS FAILURE
FORWARDER OR LB-AWARE SWITCH DETECTS FAILURE
FORWARDER AND/OR CLASSIFIER DETECTS FAILURE
CLASSIFIER OR REQUEST ROUTER DETECTS FAILURE
3106(A)
3106(B)
3106(C)
3106(D)
3106(E)
PACKETS REDIRECTED TO OTHER FORWARD-ER(S)
PACKETS REDIRECTED TO OTHER CLASSI-FIER(S)
PACKETS REDIRECTED TO OTHER REQUEST ROUTER(S)
REDUNDANCY AND DISTRIBUTION FOR FAILURE HANDLING
REDUNDANCY AND INTRINSIC FAILURE HANDLING
3108(A)
3108(B)
3108(C)
3108(D)
3108(E)
ROUTES REBUILT WITH DAM
SESSION INFORMATION REBUILT WITH DAM
SESSION INFORMATION AND/OR ROUTES REBUILT WITH DAM
DAM RE-DISTRIBUTED AND RE-REPLICATED
MESSAGE PROTOCOL USED TO REBUILD CONSOL-IDATED CACHE

FIG. 31

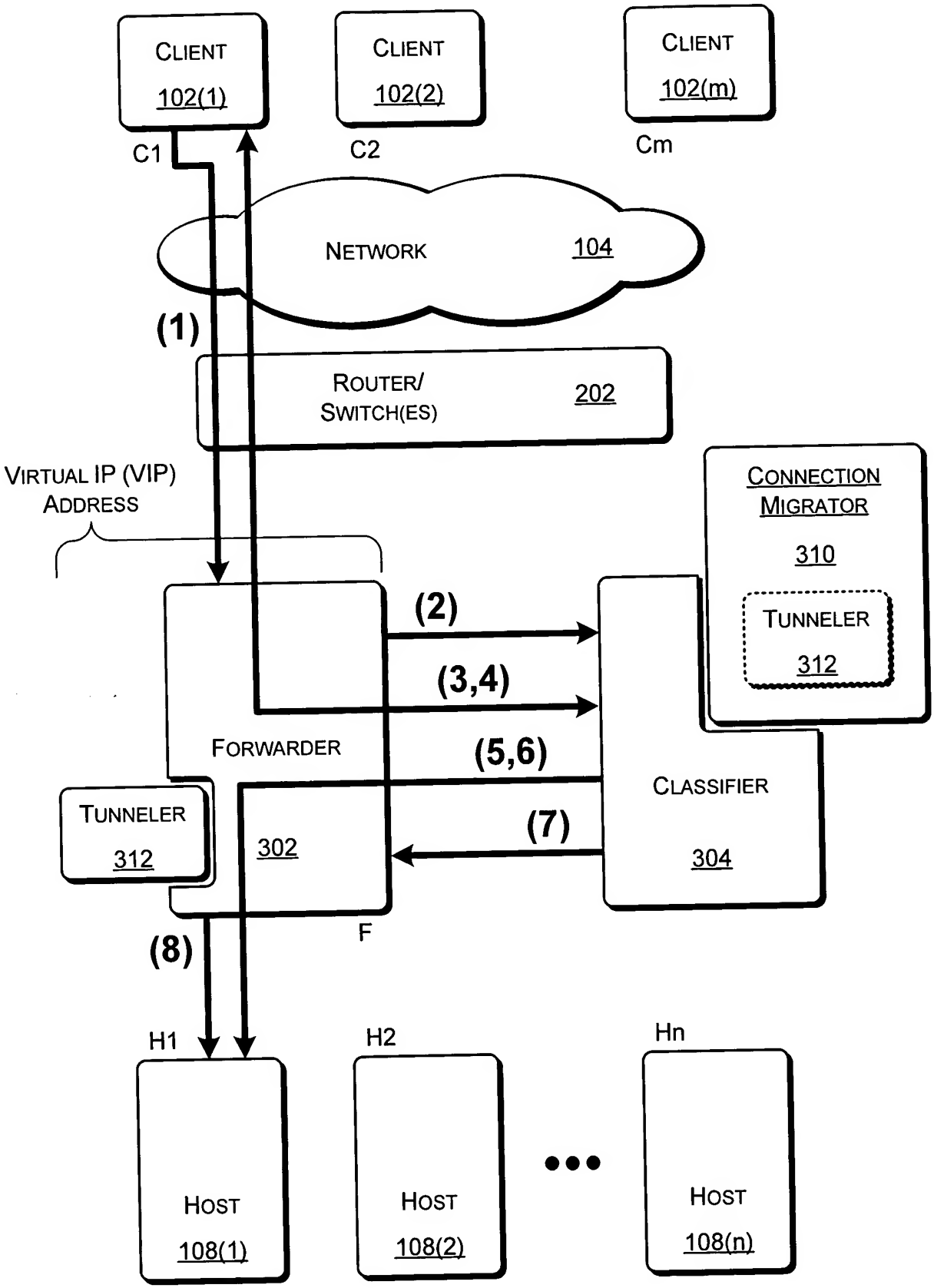

CLIENT
102(1)
CLIENT
102(2)
CLIENT
102(m)
C1
C2
Cm
NETWORK
104
(1)
ROUTER/
SWITCH(ES)
202
VIRTUAL IP (VIP)
ADDRESS
CONNECTION
MIGRATOR
310
TUNNELER
312
(2)
(3,4)
FORWARDER
(5,6)
CLASSIFIER
TUNNELER
312
302
(7)
304
F
(8)
H1
H2
Hn
HOST
108(1)
HOST
108(2)
HOST
108(n)

FIG. 32

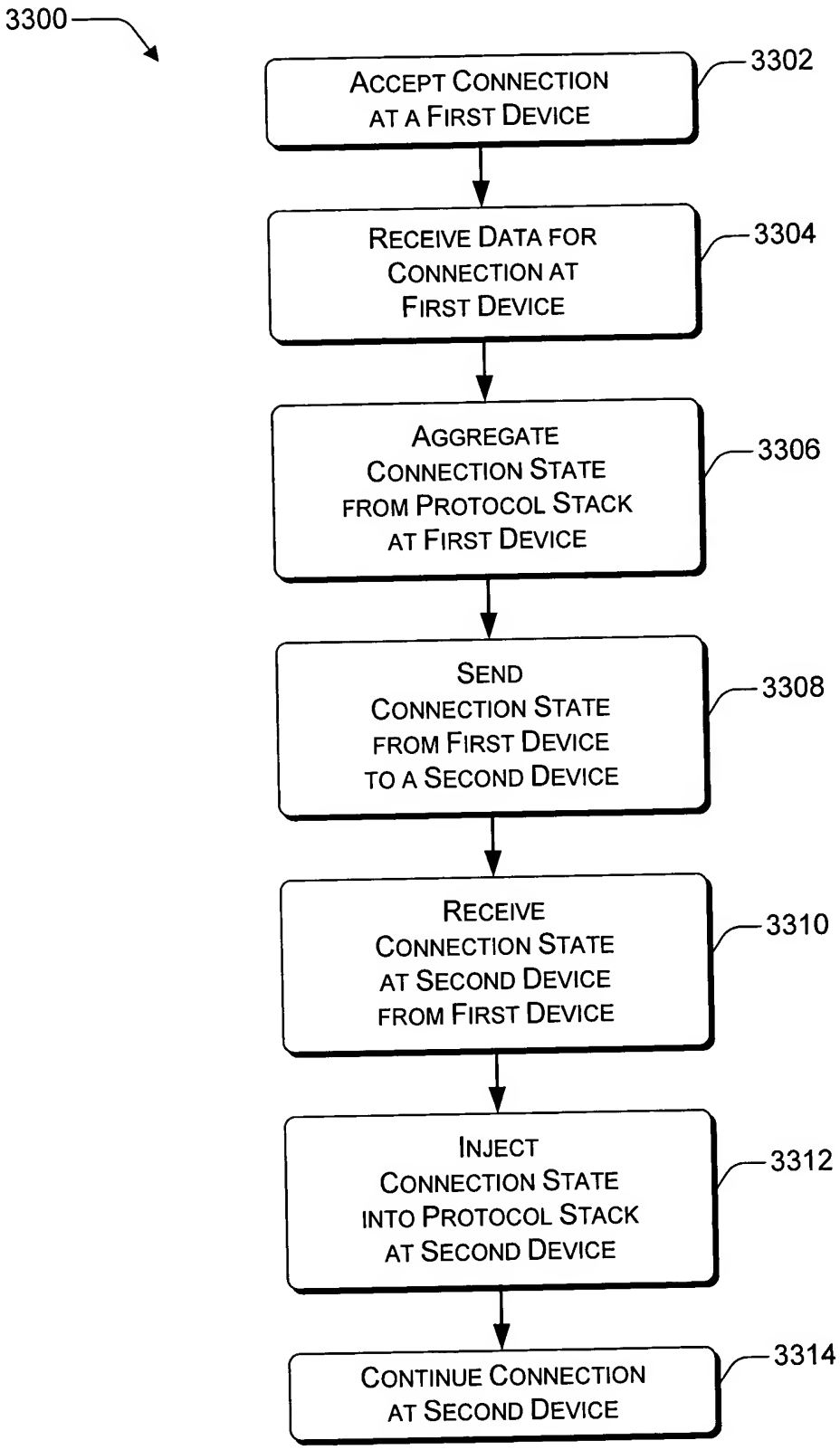

3300
ACCEPT CONNECTION AT A FIRST DEVICE
3302
RECEIVE DATA FOR CONNECTION AT FIRST DEVICE
3304
AGGREGATE CONNECTION STATE FROM PROTOCOL STACK AT FIRST DEVICE
3306
SEND CONNECTION STATE FROM FIRST DEVICE TO A SECOND DEVICE
3308
RECEIVE CONNECTION STATE AT SECOND DEVICE FROM FIRST DEVICE
3310
INJECT CONNECTION STATE INTO PROTOCOL STACK AT SECOND DEVICE
3312
CONTINUE CONNECTION AT SECOND DEVICE
3314

FIG. 33

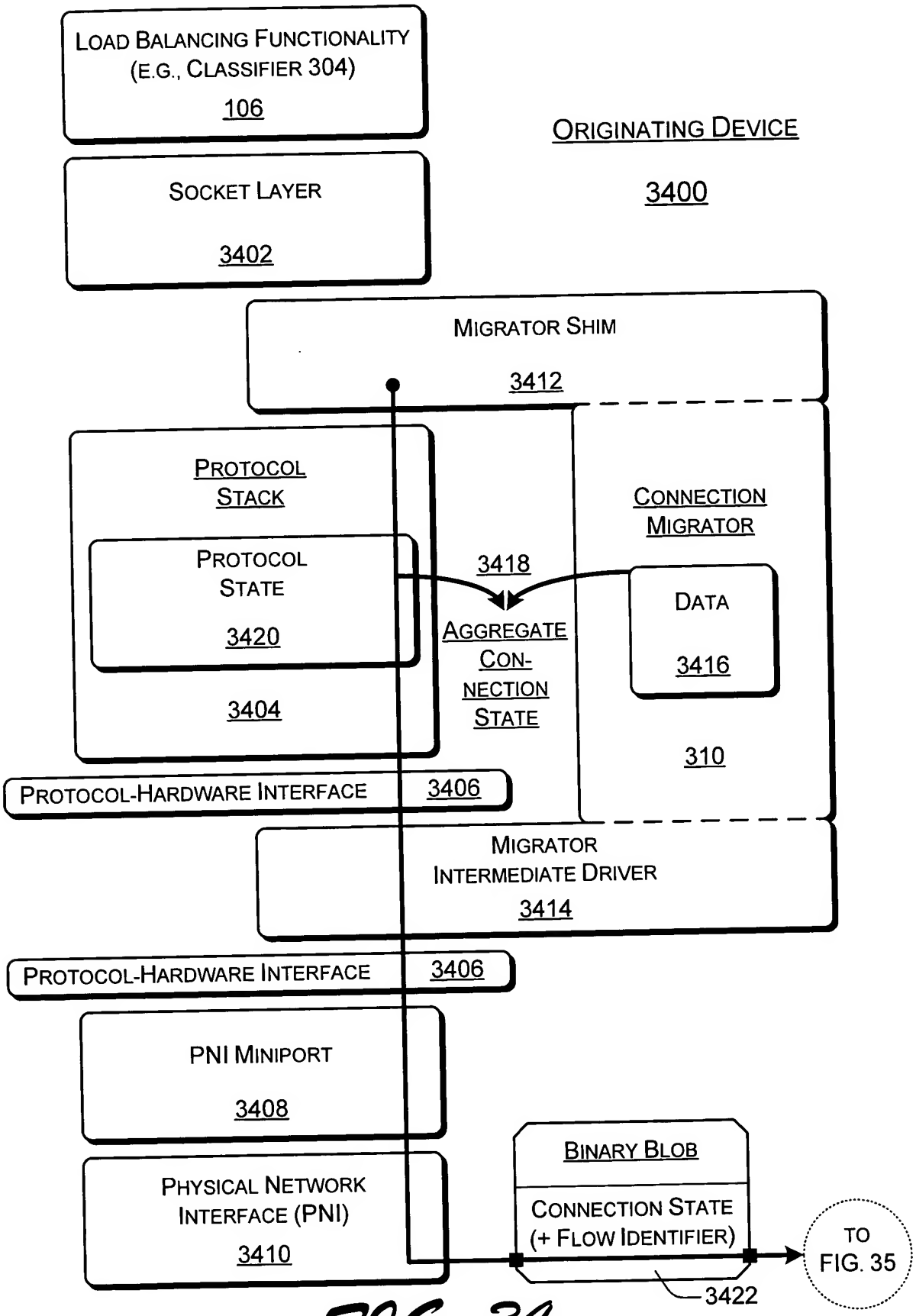

LOAD BALANCING FUNCTIONALITY
(E.G., CLASSIFIER 304)
106
ORIGINATING DEVICE
3400
SOCKET LAYER
3402
MIGRATOR SHIM
3412
PROTOCOL STACK
PROTOCOL STATE
3420
3404
3418
AGGREGATE CON-NECTION STATE
CONNECTION MIGRATOR
DATA
3416
310
PROTOCOL-HARDWARE INTERFACE
3406
MIGRATOR INTERMEDIATE DRIVER
3414
PROTOCOL-HARDWARE INTERFACE
3406
PNI MINIPORT
3408
PHYSICAL NETWORK INTERFACE (PNI)
3410
BINARY BLOB
CONNECTION STATE
(+ FLOW IDENTIFIER)
3422
TO FIG. 35

FIG. 34

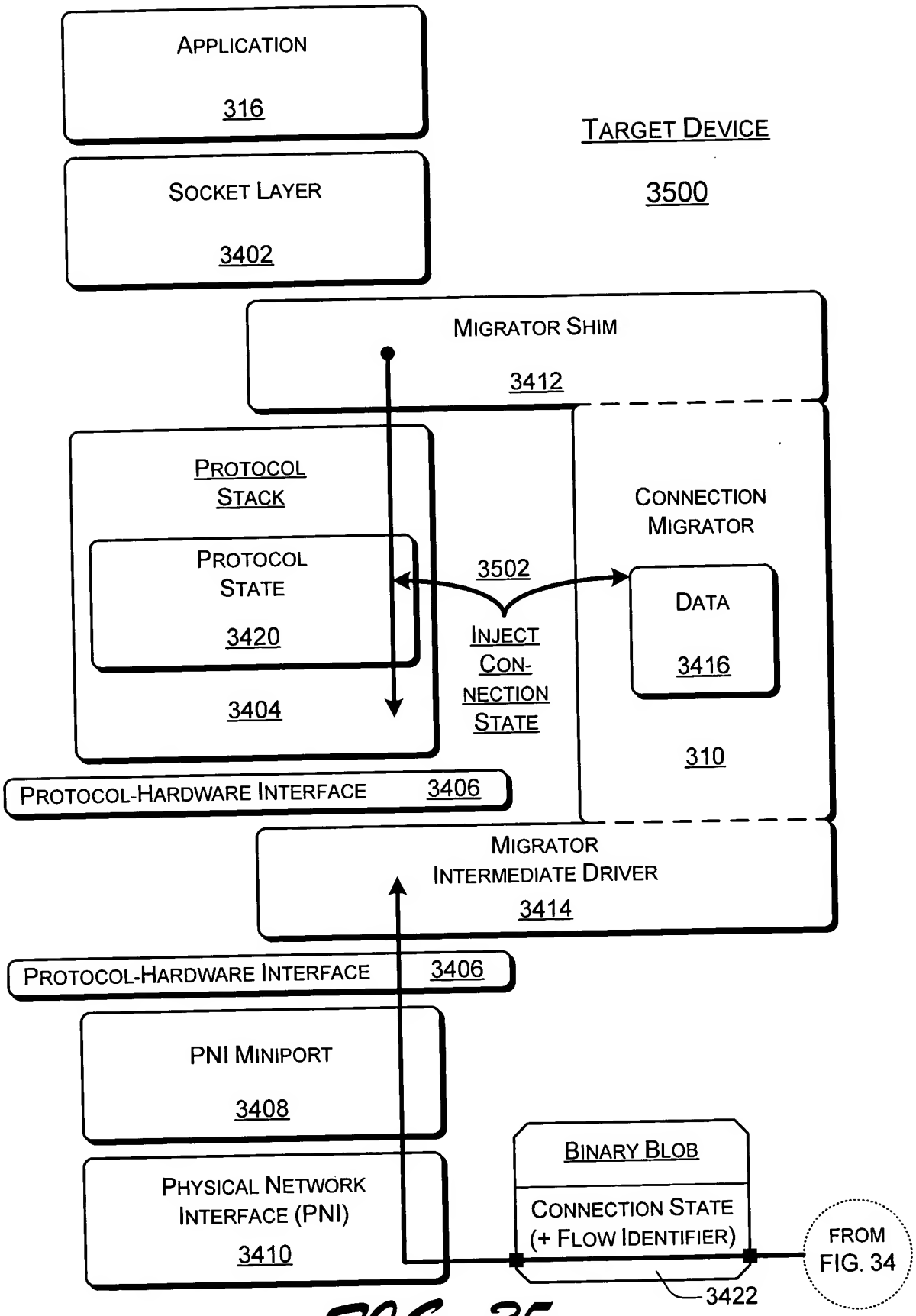

APPLICATION
316
SOCKET LAYER
3402
TARGET DEVICE
3500
MIGRATOR SHIM
3412
PROTOCOL STACK
PROTOCOL STATE
3420
3404
3502
INJECT CON-NECTION STATE
CONNECTION MIGRATOR
DATA
3416
310
PROTOCOL-HARDWARE INTERFACE 3406
MIGRATOR INTERMEDIATE DRIVER
3414
PROTOCOL-HARDWARE INTERFACE 3406
PNI MINIPORT
3408
PHYSICAL NETWORK INTERFACE (PNI)
3410
BINARY BLOB
CONNECTION STATE (+ FLOW IDENTIFIER)
3422
FROM FIG. 34

FIG. 35

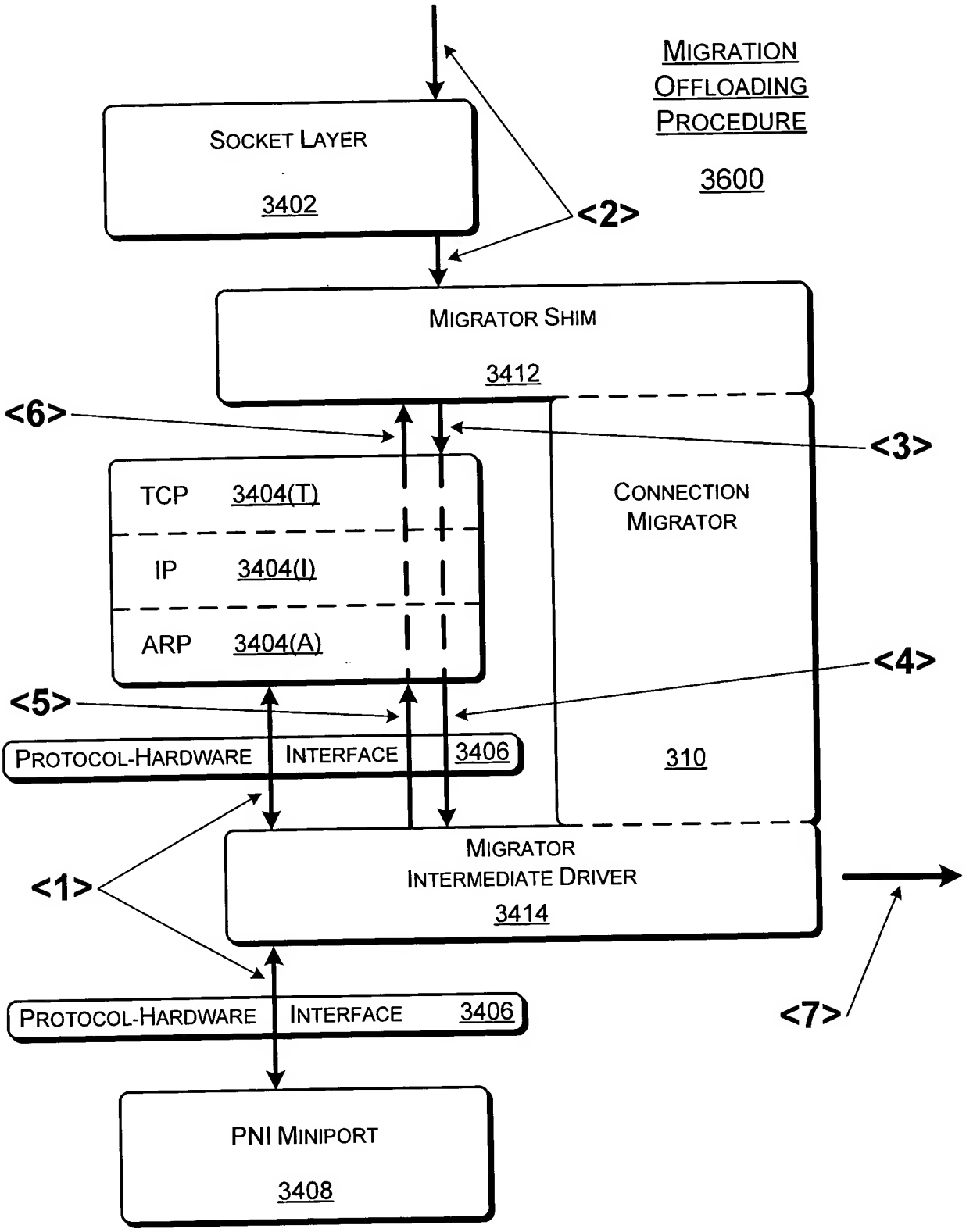

MIGRATION
OFFLOADING
PROCEDURE
3600
SOCKET LAYER
3402
<2>
MIGRATOR SHIM
3412
<6>
<3>
TCP 3404(T)
IP 3404(I)
ARP 3404(A)
CONNECTION
MIGRATOR
<4>
<5>
PROTOCOL-HARDWARE INTERFACE 3406
310
MIGRATOR
INTERMEDIATE DRIVER
3414
<1>
<7>
PROTOCOL-HARDWARE INTERFACE 3406
PNI MINIPORT
3408

FIG. 36

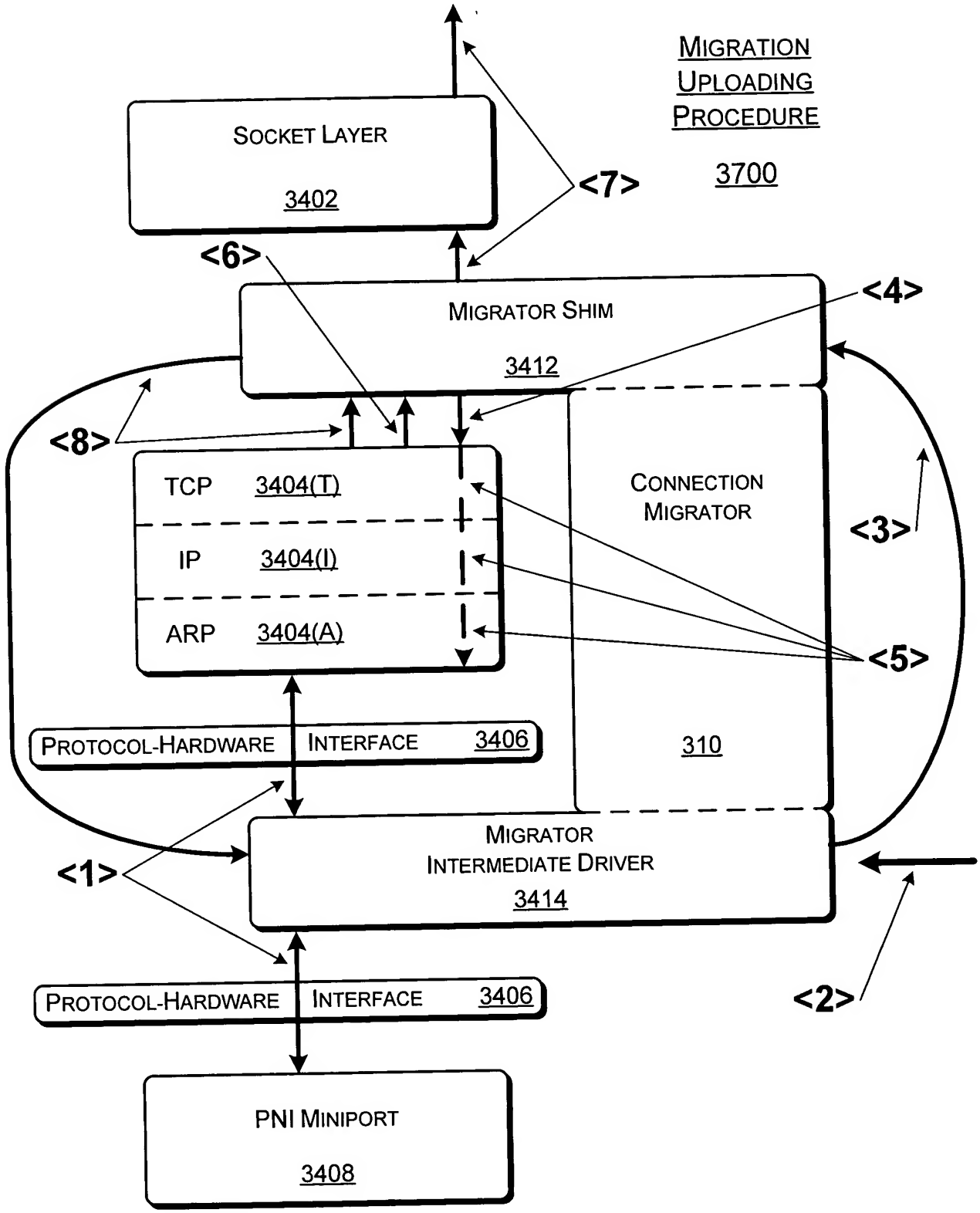

MIGRATION
UPLOADING
PROCEDURE
3700
SOCKET LAYER
3402
<7>
<6>
MIGRATOR SHIM
3412
<4>
<8>
TCP 3404(T)
IP 3404(I)
ARP 3404(A)
CONNECTION
MIGRATOR
<3>
<5>
PROTOCOL-HARDWARE INTERFACE 3406
310
MIGRATOR
INTERMEDIATE DRIVER
3414
<1>
<2>
PROTOCOL-HARDWARE INTERFACE 3406
PNI MINIPORT
3408

FIG. 37

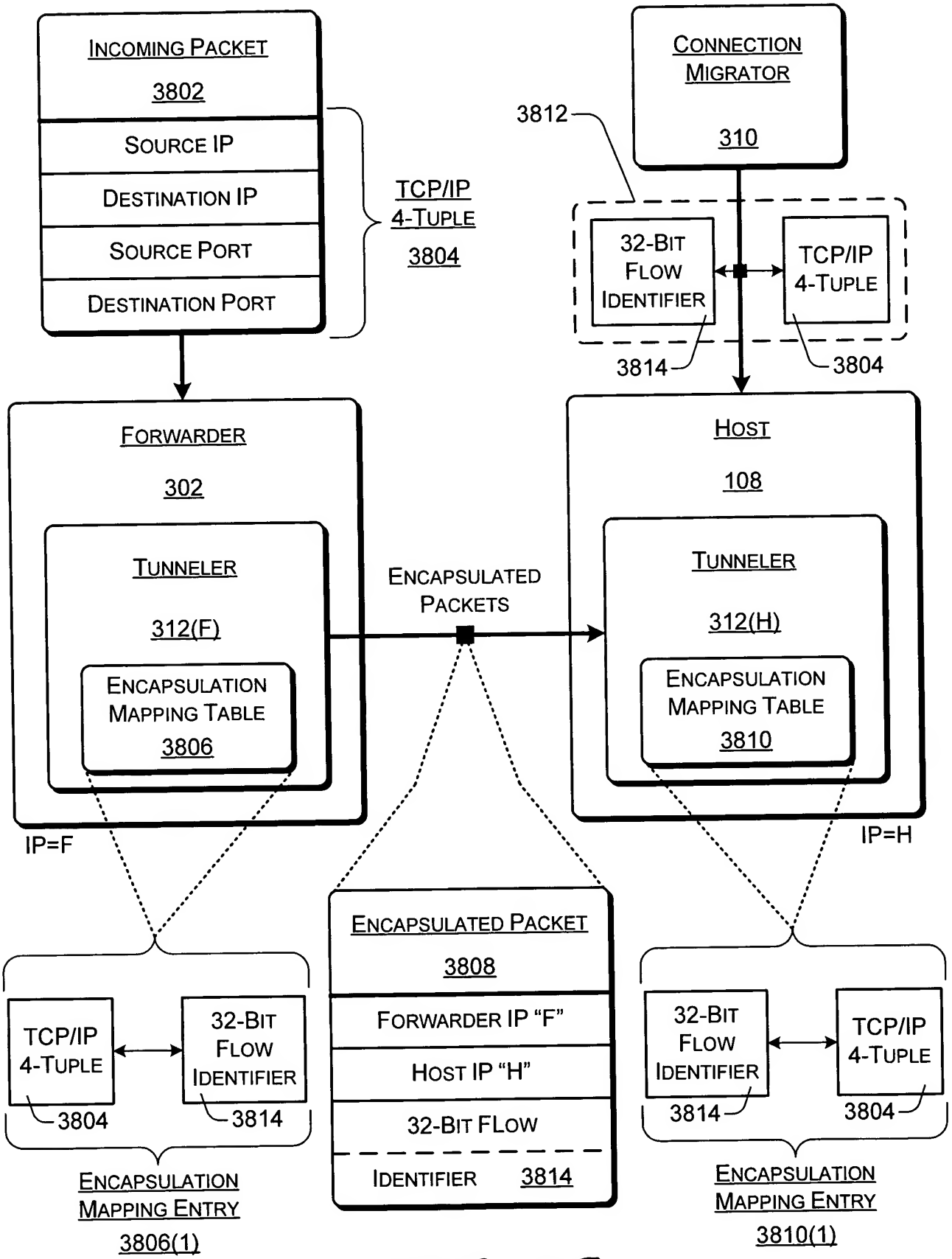

INCOMING PACKET
3802
SOURCE IP
DESTINATION IP
SOURCE PORT
DESTINATION PORT
TCP/IP
4-TUPLE
3804
CONNECTION
MIGRATOR
310
3812
32-BIT
FLOW
IDENTIFIER
TCP/IP
4-TUPLE
3814
3804
FORWARDER
302
TUNNELER
312(F)
ENCAPSULATION
MAPPING TABLE
3806
IP=F
ENCAPSULATED
PACKETS
HOST
108
TUNNELER
312(H)
ENCAPSULATION
MAPPING TABLE
3810
IP=H
ENCAPSULATED PACKET
3808
FORWARDER IP "F"
HOST IP "H"
32-BIT FLOW
IDENTIFIER 3814
TCP/IP
4-TUPLE
32-BIT
FLOW
IDENTIFIER
3804
3814
ENCAPSULATION
MAPPING ENTRY
3806(1)
32-BIT
FLOW
IDENTIFIER
TCP/IP
4-TUPLE
3814
3804
ENCAPSULATION
MAPPING ENTRY
3810(1)

FIG. 38

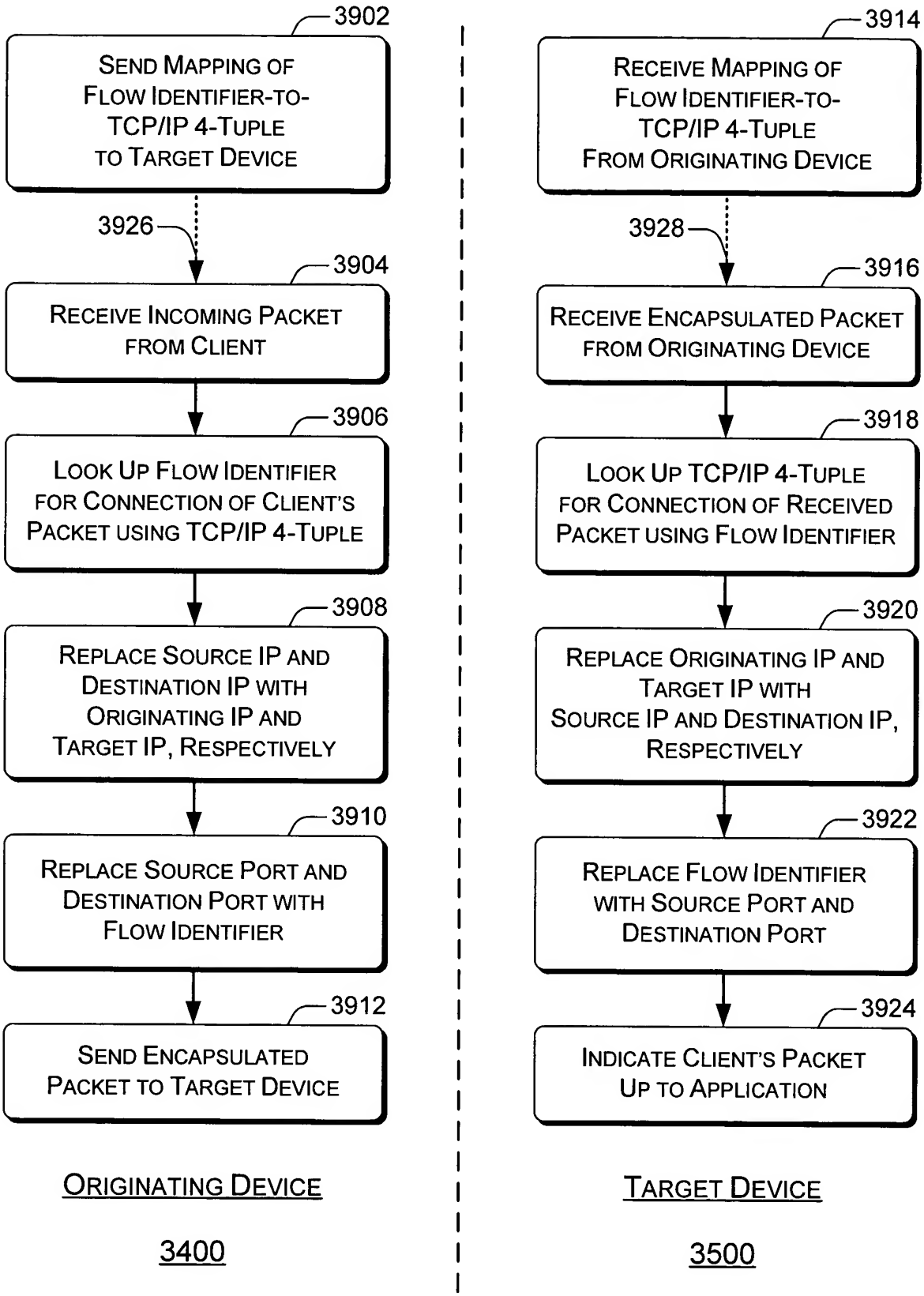

3902
SEND MAPPING OF FLOW IDENTIFIER-TO-TCP/IP 4-TUPLE TO TARGET DEVICE
3926
3904
RECEIVE INCOMING PACKET FROM CLIENT
3906
LOOK UP FLOW IDENTIFIER FOR CONNECTION OF CLIENT'S PACKET USING TCP/IP 4-TUPLE
3908
REPLACE SOURCE IP AND DESTINATION IP WITH ORIGINATING IP AND TARGET IP, RESPECTIVELY
3910
REPLACE SOURCE PORT AND DESTINATION PORT WITH FLOW IDENTIFIER
3912
SEND ENCAPSULATED PACKET TO TARGET DEVICE
ORIGINATING DEVICE
3400
3914
RECEIVE MAPPING OF FLOW IDENTIFIER-TO-TCP/IP 4-TUPLE FROM ORIGINATING DEVICE
3928
3916
RECEIVE ENCAPSULATED PACKET FROM ORIGINATING DEVICE
3918
LOOK UP TCP/IP 4-TUPLE FOR CONNECTION OF RECEIVED PACKET USING FLOW IDENTIFIER
3920
REPLACE ORIGINATING IP AND TARGET IP WITH SOURCE IP AND DESTINATION IP, RESPECTIVELY
3922
REPLACE FLOW IDENTIFIER WITH SOURCE PORT AND DESTINATION PORT
3924
INDICATE CLIENT'S PACKET UP TO APPLICATION
TARGET DEVICE
3500
3900

FIG. 39

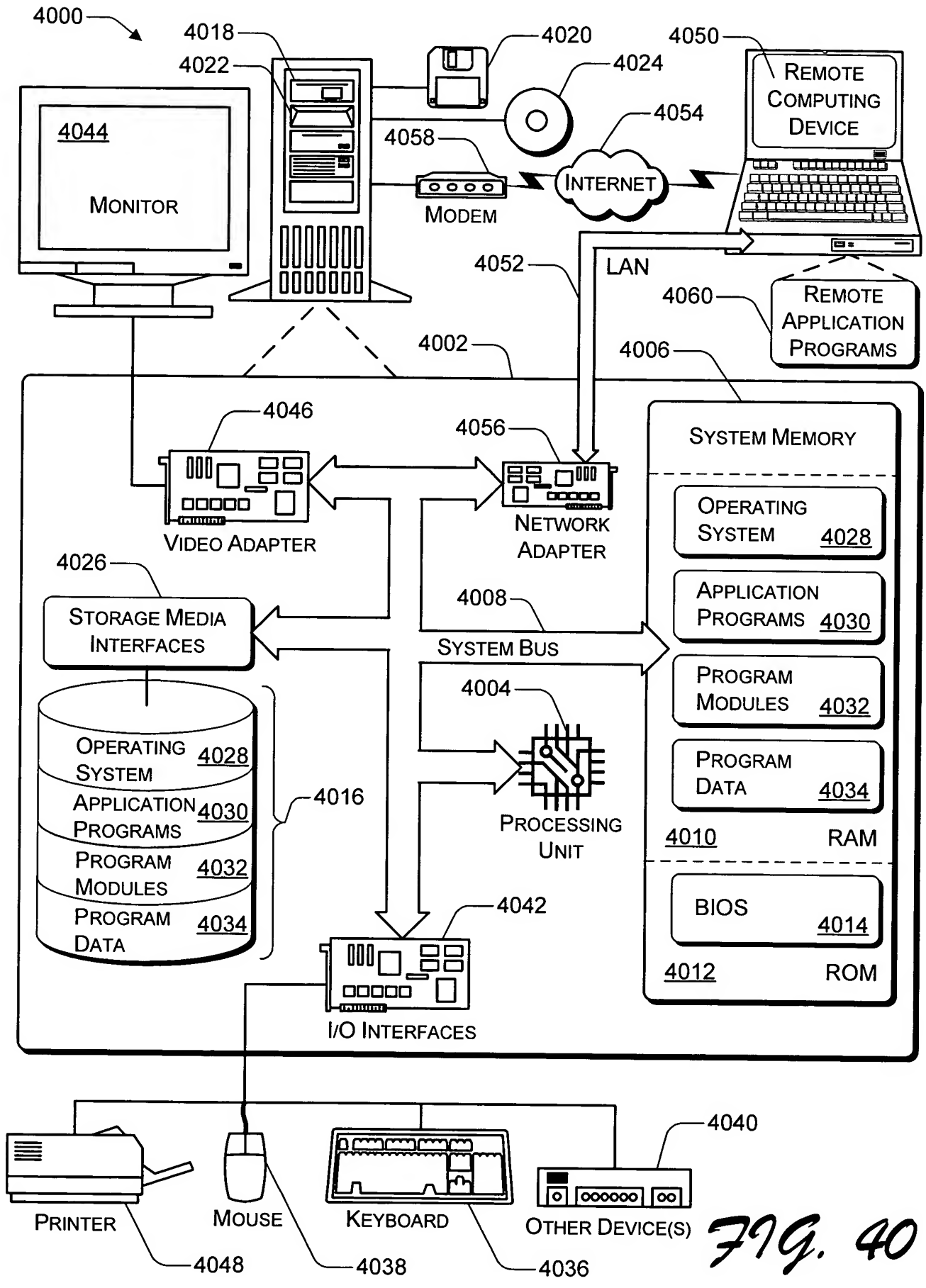

4000
4018
4022
4020
4024
4050
REMOTE COMPUTING DEVICE
4044
MONITOR
4058
MODEM
4054
INTERNET
4052
LAN
4060
REMOTE APPLICATION PROGRAMS
4002
4006
4046
4056
SYSTEM MEMORY
VIDEO ADAPTER
NETWORK ADAPTER
OPERATING SYSTEM 4028
4026
STORAGE MEDIA INTERFACES
4008
APPLICATION PROGRAMS 4030
SYSTEM BUS
PROGRAM MODULES 4032
4004
OPERATING SYSTEM 4028
APPLICATION PROGRAMS 4030
PROGRAM MODULES 4032
PROGRAM DATA 4034
4016
PROCESSING UNIT
PROGRAM DATA 4034
4010
RAM
BIOS 4014
4042
4012
ROM
I/O INTERFACES
4040
PRINTER
MOUSE
KEYBOARD
OTHER DEVICE(S)
4048
4038
4036

FIG. 40